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MARYLAND ENTOMOLOGICAL SOCIETY

The Maryland Entomological Society (MES) was founded in November 1971, to promote the science of entomology in all its sub-disciplines; to provide a common meeting venue for professional and amateur entomologists residing in Maryland, the District of Columbia, and nearby areas; to issue a periodical and other publications dealing with entomology; and to facilitate the exchange of ideas and information through its meetings and publications. The MES was incorporated in April 1982 and is a 501(c)(3) non-profit, scientific organization.

The MES logo features an illustration of ***Euphydryas phaëton*** (Drury), the Baltimore Checkerspot, with its generic name above and its specific epithet below (both in capital letters), all on a pale green field; all these are within a yellow ring double-bordered by red, bearing the message "● Maryland Entomological Society ● 1971 ●". All of this is positioned above the Shield of the State of Maryland. In 1973, the Baltimore Checkerspot was named the official insect of the State of Maryland through the efforts of many MES members.

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Editor's Note

This issue of *The Maryland Entomologist* contains seven articles and notes submitted by members of the Maryland Entomological Society.

Warren E. Steiner, Jr. documents four species of chewing lice (Insecta: Phthiraptera) found on a single Wild Turkey in Maryland.

Frank G. Guarnieri and Phillip J. Harpootlian provide an illustrated key and commentary for Maryland's earth-boring scarab beetles in the genus *Geotrupes* Latreille (Coleoptera: Geotrupidae) including notes on *G. ulkei* Blanchard, a rare southern species recently discovered in Morgan County, West Virginia.

Chris Sargent, Holly M. Martinson, Richard A. Bean, Samuel Grimard, Brian Raupp, Sarah C. Bass, Erik J. Bergmann, David J. Nowak, and Michael J. Raupp present approaches for predicting movement and potential economic and ecological impacts, as well as presenting management options, for the Emerald Ash Borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in Maryland municipalities.

Warren E. Steiner, Jr. summarizes records of the darkling beetle *Prateus fusculus* LeConte (Coleoptera: Tenebrionidae) in Maryland and West Virginia including observations on its habitats and known distribution.

Richard H. Smith, Jr. documents the first Maryland records of the Dainty Sulphur, *Nathalis iole* Boisduval (Lepidoptera: Pieridae: Coliadinae).

Samuel W. Droege investigates the spring bee fauna (Hymenoptera: Apoidea) of seven woodland sites on Maryland's Coastal Plain using continuously-trapping arrays of propylene glycol cup traps.

Eugene J. Scarpulla reports on his yearlong survey of the bees (Hymenoptera: Apoidea) of Hart-Miller Island, Chesapeake Bay, Baltimore County, Maryland: a human-made habitat created from dredged material.

This year's submitted articles and notes again show the excellent studies being conducted, and the notable discoveries being made, by members of the Maryland Entomological Society. I thank the authors for their submittals that further our knowledge of the insects of Maryland. I express my gratitude to the named and anonymous peer reviewers for their insightful comments that have enhanced each publication.

Eugene J. Scarpulla
Editor

Four Species of Lice (Insecta: Phthiraptera) from a Single Wild Turkey in Maryland

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Emerson (1962) provided a key and illustrations for the four species of chewing lice (Insecta: Phthiraptera: Menoponidae and Philopteridae) known to infest the Wild Turkey, *Meleagris gallopavo* Linnaeus (Aves: Galliformes: Phasianidae), with this being the type-host of each (Price et al. 2003). Published lists and catalogs do not generally document co-occurrences of species on single birds; one record lists three of the species on one turkey and two of the species from five other individual birds from Sonoma County, California (Lane et al. 2006), and three species were reported from a single bird from Virginia (Hill and Eckerlin 1994). A collection of all four louse species from a single Wild Turkey in Maryland is reported here.

The adult male turkey was killed near Wittman, Talbot County, Maryland at about 1930 hours on 18 May 2012, kept chilled overnight, and prepared on the following morning. Lice and ticks were seen active on the feathers and skin of the breast and lower neck. The breast and lower neck skin patch (ca. 970 cm^2 [150 in^2]) was placed in a plastic bag and refrigerated for later examination on 21 May when many live lice and ticks were collected by hand and preserved in 80% ethanol. The skin was then frozen, killing the remaining parasites; a final examination of the thawed material, including shaking and brushing the feathers over a large plastic bin, yielded many more specimens. These were sorted into vials by species and bear the following label data:

> "MARYLAND: Talbot Co., Wittman, at Harris Cr., 38°47'33"N, 76°16'46"W, 18 May 2012, coll. W. E. Steiner, *ex Meleagris gallopavo* skin & feathers on breast & neck".

Identifications were made using the key of Emerson (1962) and by comparison of details illustrated in that work. Specimens are deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia, USA.

The total number of lice in the sample was 2,559, including both adults (A) and nymphs (N), enumerated as follows. Most abundant was the Large Turkey Louse, *Chelopistes meleagridis* (Linnaeus) (Philopteridae), (Figure 1) (504 A, 1,442 N). The cosmopolitan Chicken Body Louse, *Menacanthus stramineus* (Nitzsch) (Menoponidae), (Figure 2) was second in abundance (313 A, 167 N). Less common were the Slender Turkey Louse, *Oxylipeurus polytrapezius* (Burmeister) (Philopteridae), (Figure 3) (56 A) and its congener *Oxylipeurus corpulentus* Clay (Figure 4) (41 A); 36 *Oxylipeurus* nymphs could not be identified. Also collected were 42 nymphs of the Lone Star Tick, *Amblyomma*

Figure 1. ***Chelopistes meleagridis* (Linnaeus).** Male, left; female, right. Body length 3.0-3.3 mm (0.12-0.13 in).

Figure 2. ***Menacanthus stramineus* (Nitzsch).** Male, left; female, right. Body length 2.7-3.1 mm (0.11-0.12 in).

Figure 3. ***Oxylipeurus polytrapezius* (Burmeister).** Male, left; female, right. Body length 3.5-3.7 mm (0.14-0.15 in).

Figure 4. ***Oxylipeurus corpulentus* Clay.** Male, left; female, right. Body length 3.6-3.8 mm (0.14-0.15 in).

americanum (Linnaeus) (Acari: Ixodidae). In spite of the dense infestation found, the bird appeared to be healthy with no observed skin lesions or discoloration.

Four other louse species are known to occur on turkeys (Price et al. 2003), but these have other type-host bird species, have been found mostly on domestic birds, and are not North American records.

Oxylipeurus corpulentus is the least commonly collected species of the four reported in this note; Kellogg et al. (1969) also found this species only occasionally in a survey of 176 turkeys in the southeastern states, with the other three species common, but co-occurrence on single birds was not reported. Emerson (1962) saw *O. corpulentus* specimens from several states ranging from Texas to the Carolinas; Hill and Eckerlin (1994) reported it from Northampton County, Virginia, where it co-occurred with *O. polytrapezius* and *C. meleagridis* on a young male turkey. The Maryland occurrence apparently represents a new state record and northern range extension for *O. corpulentus*. Maryland records for the three other species are apparently not listed in literature, but these lice are known to occur worldwide on domestic turkeys (Emerson 1962). Earlier distributional listings (Emerson 1951) do not include Maryland but indicate a wide distribution in North America.

ACKNOWLEDGMENTS

Ralph P. Eckerlin (Former Professor, Natural Science Department, Northern Virginia Community College) provided very helpful information on review of an early draft of this note, and comments on the manuscript by Harold J. Harlan (Entomologist, Armed Forces Pest Management Board, Silver Spring, Maryland) and two anonymous reviewers are appreciated. Smithsonian Institution Technical Staff Gary F. Hevel (Public Information Officer [Emeritus]) and Floyd W. Shockley (Collections Management) assisted with providing literature. The turkey was taken during the spring hunting season and recorded with Maryland Department of Natural Resources confirmation number 3918 4051 8011.

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An Illustrated Key to the Genus *Geotrupes* Latreille (Coleoptera: Geotrupidae) of Maryland Including Notes on *G. ulkei* Blanchard, a Rare Southern Species Recently Discovered in Morgan County, West Virginia

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Abstract: Six species of *Geotrupes* Latreille (Coleoptera: Geotrupidae): *G. balyi* Jekel, *G. blackburnii* (Fabricius), *G. egeriei* Germar, *G. hornii* Blanchard, *G. semiopacus* Jekel, and *G. splendidus* (Fabricius) have been recorded from Maryland. A seventh species, *G. ulkei* Blanchard, was recently discovered near Paw Paw, West Virginia. The occurrence of *G. ulkei* in West Virginia represents a new state record, and as the beetles were found just south of the Potomac River it is possible that the species may occur in Maryland as well. The seven *Geotrupes* that occur or possibly occur in Maryland can be separated by characters easily seen on the dorsal surface and a photographic key is provided to facilitate rapid identification. Brief notes on ecology and distribution in the state are given.

INTRODUCTION

Staines (1984) lists seven species of *Geotrupes* Latreille (Coleoptera: Geotrupidae) in his checklist of Maryland Scarabaeoidea. Six species, G. *balyi* Jekel, *G. blackburnii* (Fabricius), *G. egeriei* Germar, *G. hornii* Blanchard, *G. semiopacus* Jekel, and *G. splendidus* (Fabricius), have been collected in the state. *Geotrupes ulkei* Blanchard has not been found in Maryland but was included by Staines (1984) based on an historical reference to that species in Virginia (Howden 1955). Glaser's (1987) addendum added no additional species for Maryland. Recently, the first author identified a population of *G. ulkei* in Morgan County, West Virginia. We are unaware of any previously published records of *G. ulkei* occurring in West Virginia and the proximity of the collecting site, just 10 km (6.2 mi) from the Potomac River, raises the possibility that the species might be found in Allegany and/or Washington Counties, Maryland as well.

Despite their superficial similarity, all seven species can be quickly distinguished by characters on the dorsal surface that are readily seen at low magnification. A photographic key, adapted from Howden (1955) and Harpootlian (2001), is provided below that will allow for rapid and accurate identification of all species that occur in or near Maryland.

In total there are nine species of *Geotrupes* in North America north of Mexico (Howden 1955). All occur in the eastern United States, but two species are not included in the key

as they have not been reported from Maryland and are unlikely to be found in the Middle Atlantic region based on their known ranges. *Geotrupes opacus* Haldeman occurs in the Midwest and south central United States (Indiana, Illinois, Kansas, Missouri, Oklahoma, and Texas) (Howden 1955), and *G. stercorarius* (Linnaeus) is an introduced European species that has become established in New Brunswick, Nova Scotia, and Maine (Dearborn and Donahue 1993; Howden 1955).

Unlike *G. ulkei*, which is rarely collected and so far is known to be quite local in distribution, most *Geotrupes* species are common and generally widespread over much of the eastern United States. In Maryland, it is quite easy to find one or more of the six recorded species virtually anywhere in the state (excluding urban and suburban habitats) in all but the coldest months of the year. They are typically found in association with dung, fungi, decaying vegetation, or carrion (Howden 1955; Ritcher 1958; Harpootlian 2001; Jameson 2002) and are presumed to play an important role as scavengers in diverse habitats throughout the region.

ILLUSTRATED KEY TO MARYLAND SPECIES OF *GEOTRUPES*

1a. Elytra with rows of punctures but lacking distinct striae............ ***G. ulkei* Blanchard** (Figure 1)
1b. Elytra with distinct striae.. 2

Figure 1. *Geotrupes ulkei* Blanchard. Elytral detail showing indistinct striae.

2a. Elytral striae impunctate... ***G. semiopacus* Jekel** (Figure 2)
2b. Elytral striae with distinct punctures.. 3

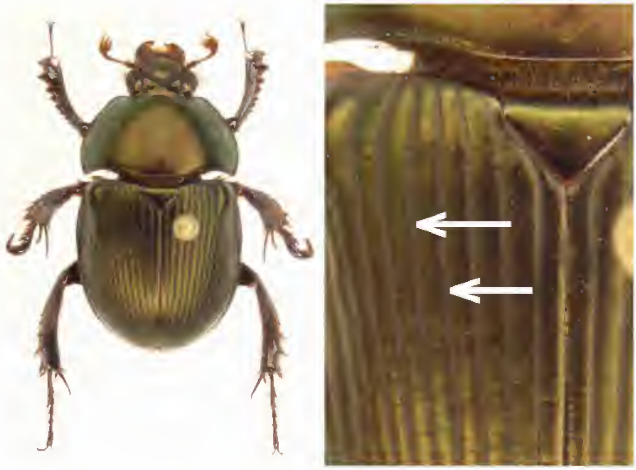

Figure 2. *Geotrupes semiopacus* Jekel. Elytral detail showing impunctate striae.

3a. Elytral striae with punctures that are brightly iridescent and colored differently from background.. ***G. egeriei* Germar** (Figure 3)
3b. Elytral striae with puncture that are colored the same as background.......................... 4

Figure 3. *Geotrupes egeriei* Germar. Elytral detail showing bright blue pits within the striae.

4a. Sutural striae end at the scutellum.. 5 (Figure 4, left)
4b. Sutural striae extend forward alongside the scutellum....................... 6 (Figure 4, right)

Figure 4. Sutural striae details. Left: ending at the scutellum (*G. blackburnii*); Right: extending forward alongside the scutellum (*G. hornii*).

5a. Upper surface typically dark bronze, central disk of pronotum with a small number of fine punctures.. ***G. blackburnii* (Fabricius)** (Figure 5)
5b. Upper surface typically with bright metallic reflections, central disk of pronotum with scattered coarse punctures.................................... ***G. splendidus* (Fabricius)** (Figure 6)

Figure 5. ***Geotrupes blackburnii*** **(Fabricius).**

Figure 6. ***Geotrupes splendidus*** **(Fabricius).**

6a. Dorsal color variable but always with metallic reflections..... ***G. balyi* Jekel** (Figure 7)
6b. Dorsal color black and shiny but without metallic reflections.............................
.... ***G. hornii* Blanchard** (Figure 8)

Figure 7. *Geotrupes balyi* Jekel

Figure 8. *Geotrupes hornii* Blanchard

BRIEF SPECIES COMMENTARY

Species lengths and North American ranges are referenced from Howden (1955).

***G. balyi*:** 10-16 mm (0.4-0.6 in), variable in color but usually shiny black with dark metallic green or bluish reflections. The range includes Georgia and Tennessee north to Iowa, Wisconsin, Maine, and Quebec. Staines (1984) obtained Maryland records by surveying specimens at the Maryland Department of Agriculture, the University of Maryland, and the United States National Museum, as well those of E. J. Ford, W. E. Steiner, and his own private collection. *Geotrupes balyi* has been found in Anne Arundel, Baltimore, and Somerset Counties. Collecting dates ranged from July to September. They were associated with fungi in wooded areas.

***G. blackburnii*:** 10-18 mm (0.4-0.7 in), black with a distinct bronze luster. The range includes Florida to New Hampshire west to Tennessee and Ohio with a subspecies, *G. b. excrementi*, occurring in a more western distribution from Texas to Wisconsin. In Maryland, Staines (1984) reports collection dates from March to November in Allegany, Baltimore, Charles, Harford, Prince George's, and Wicomico Counties. Collecting data include dung, carrion, fungi, chicken feathers, malt traps, and light. According to Howden (1955), the adults dig a shallow burrow that is packed with either dung or leaf litter for the larvae to feed. The first author has noted this species to be quite tolerant of cold temperatures and has observed activity on early spring days (e.g., Baltimore County,

Hereford, 31 March 2006 – dung baited pitfall trap) and late fall nights (e.g., Caroline County, Martinak State Park, 21 October 2000 – collected at light [Guarnieri 2010]).

***G. egeriei*:** 11-20 mm (0.4-0.8 in), dark metallic green, blue, or purple. The elytral striae have punctures that are brightly colored, as well as dense and deep, creating somewhat of a "waffle iron" appearance. These beetles tend to be more robust and convex dorsally and laterally than our other species. This species ranges broadly across the eastern United States from Florida and Louisiana north to Illinois, Michigan, and New Hampshire. In Maryland, Staines (1984) reports the species from April to September in Prince George's County. Collecting data include dung, fungi, rotten fruit, and malt traps. The first author has two specimens from Caroline County (Hillsboro, 25 July 1998 – collected at light; and Tuckahoe State Park, 23 July 2005 – collected at light [Guarnieri 2010]).

***G. hornii*:** 12-18 mm (0.5-0.7 in), shiny black without any colored iridescence. The range extends from Georgia and Mississippi north to Wisconsin, Maine, and into Newfoundland. Staines (1984) lists the species from July to October in Montgomery, Prince George's, and Talbot Counties. Collecting data include fungi, dung, and light. The first author has additional specimens from Anne Arundel County (Annapolis, 1 August 1984 and 11 July 1988 – both collected at light) and Caroline County (Tuckahoe State Park, 23 July 2005 and 3 August 2006 – both collected at light [Guarnieri 2010]).

***G. semiopacus*:** 13-20 mm (0.5-0.8 in), reddish or greenish bronze. This species is readily identified by their impunctate elytral striae. The range includes North Carolina and Tennessee north to Manitoba, Ontario, and Quebec. Staines (1984) reports from April to October in Frederick, Garrett, Montgomery, Prince George's, Talbot, Washington, and Wicomico Counties. Beetles have been collected on fungi in wooded areas. The first author found the species to be readily attracted to dung-baited pitfall traps at Hereford, Baltimore County (many observed between 20 July and 6 September 2005).

***G. splendidus*:** 13-18 mm (0.5-0.7 in), brassy or copper-colored with bright blue, green, or red reflections. *Geotrupes splendidus* is similar to *G. blackburnii* but typically is more vividly colored and with coarser punctation on the pronotum. Also, *G. splendidus* is slightly more robust and has deeper punctures in the elytral striae (although these latter two characteristics not as pronounced as with *G. egeriei*). The range includes the eastern United States west to Arizona and Nebraska and north to Ontario and Quebec. Staines (1984) lists collection dates from May to October in Baltimore, Caroline, Garrett, Montgomery, and Prince George's Counties. Collecting data include fungi, dung, and carrion. The first author has collected these beetles in nearby Morgan County, West Virginia (7 km [4.3 mi] east of Paw Paw, 1 June 1999 – pitfall trap baited with dung, and 26 August 2000 – pitfall trap baited with fermenting molasses).

***G. ulkei*:** 10-12 mm (0.4-0.5 in), shiny black with thin metallic blue elytral margins. This species has fused elytra and vestigial wings, two characters that may inadvertently lead to misidentification under the genus *Mycotrupes* LeConte using Howden's key.

However, *Mycotrupes* species have notably coarse granulate elytral surfaces and are only known to occur in Florida, Georgia, and South Carolina (Howden 1955; Harpootlian 2001). The lack of distinct elytral striae easily distinguish *G. ulkei* from all other *Geotrupes* species that occur in Maryland. The prior known range included scattered southern Appalachian populations in Alabama (Madison County), North Carolina (otherwise unlabeled specimens), and Virginia (Giles and Page Counties). No Maryland specimens were reported by Staines (1984).

GEOTRUPES ULKEI DISCUSSION

The first author originally observed many unidentified scarab beetles crawling in the leaf litter at night in a moist wooded ravine in Morgan County, West Virginia in August 2000 and 2002. The location was near the confluence of the Potomac and Cacapon Rivers, 7 km (4.3 mi) east of Paw Paw (39° 31.30' N, 78° 21.74' W, elevation 183 m [600 ft]). A photographic image of one of the beetles was posted on the "BugGuide" website, hosted by Iowa State University Entomology (Guarnieri 2002). It was subsequently identified as *G. ulkei* by the second author after examining a physical specimen. The site was surveyed again on the nights of 1-2 August 2012 and twenty-two specimens were seen crawling on the ground (nine were collected). Two additional individuals were collected in pitfall traps baited with fermenting molasses. None were seen in pitfall traps baited with dung. Many fragments of dead specimens were observed. The fused elytra in particular are strongly reflective and can be easily seen at night in the beam of a flashlight. Voucher specimens can be found in the two authors' private collections and also at the Cornell University Insect Collection, Ithaca, New York, and the Carnegie Museum of Natural History, Pittsburgh, Pennsylvania.

According to Howden (1955), adults are rarely encountered but have been found June through September at fungi and malt traps. The biology was first described by Loding (1935) who reported that larvae develop in tunnels that are packed with decaying leaves. Unfortunately no feeding, mating, or burrowing activities were observed at the West Virginia location. Populations of *G. ulkei* are apparently quite localized which would not be atypical for a small flightless species. On the other hand, the scarcity of collecting data could be artifactual, secondary to the beetles being secretive and thus easily overlooked. For example, individuals of *G. ulkei* do not appear to be attracted to dung and cannot fly to light, likely the two most common methods for collecting *Geotrupes* species in our area. Even though the Potomac River represents an imposing physical barrier, it does seem possible that populations of *G. ulkei* could occur in Maryland. Additional surveys of nearby sites on both sides of the river are encouraged.

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Approaches for Predicting the Movement and Potential Economic and Ecological Impacts of the Emerald Ash Borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in Maryland Municipalities and a Discussion of Possible Management Options

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ABSTRACT: The Emerald Ash Borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera, Buprestidae), an exotic invasive beetle native to Asia that is a devastating pest of ash trees, *Fraxinus* L. spp. (Oleaceae), entered Maryland in 2003 in a shipment of infested ash nursery stock. In the past decade, the rapid spread and lethal impact of EAB on ash trees in North America has put affected municipalities at risk for both financial and ecological losses from the destruction of ash trees in the urban canopy. To determine the rate of spread and potential impacts of EAB infestation and loss of ash trees on Maryland's urban forests, we analyzed EAB detection data collected by the Maryland Department of Agriculture. Additionally, we conducted ash tree surveys in select communities near the original EAB quarantine area using the i-Tree Streets software program for inventory and benefits assessments of urban street trees. Survey results were analyzed to estimate the potential reduction of benefits from the loss of street ash trees. We also processed ash tree survey information through the online Purdue University EAB Cost Calculator to generate a range of management and cost options that urban forestry managers could utilize in developing an EAB mitigation program. Based on EAB detection data from 2003 through 2010, we determined that the rate of spread of EAB in Maryland is increasing over time rather than remaining constant. In assessing the population sizes and benefits provided by street ash trees in the urban canopies of the four focal municipalities, we demonstrate that the environmental and aesthetic benefits provided exceed $1.2 million over a five-year period. These benefits are far greater than even the most expensive EAB management option over that same period (over $850,000 for removal and replacement of ash), indicating that retaining municipal ash trees in the face of EAB invasion is a viable management option.

INTRODUCTION

The Emerald Ash Borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), an aggressive exotic wood boring beetle, is native to China, Korea, Mongolia, Japan, Taiwan, and the Russian Far East. EAB likely came to North America in the mid- to late-1990s via infested wood packaging materials from shipments originating in its native range, where it is reported to attack ash, *Fraxinus* L. spp.(Oleaceae), including Chinese ashes (*F. chinensis* Roxb. var. *chinensis* and var. *rhynchophylla*) and Manchurian ash (*F. mandshurica* Rupr.). In North America, EAB has attacked several ash species, particularly green ash (*F. pennsylvanica* Marshall), white ash (*F. americana* L.), and black ash (*F. nigra* Marshall). Adult EAB (Figure 1) feed on ash leaves, causing negligible injury to the trees. However, EAB larvae (Figure 2), called flatheaded borers, feed rapaciously on the cambium layer beneath the bark (Figure 3), and large numbers of larvae can effectively girdle and kill a tree in several years. Unlike native borers which preferentially attack stressed trees, EAB attack and kill both stressed and apparently healthy trees in woodlots as well as urban landscapes (Poland and McCullough 2006). To date, EAB is responsible for the loss of tens of millions of ash trees in 18 central and northeastern states and the District of Columbia, as well as two Canadian provinces (United States Department of Agriculture [USDA] Forest Service [FS] and Michigan State University 2003).

EAB was first confirmed in Michigan and in Ontario, Canada, in 2002, and entered Maryland in April 2003 in a shipment of infested ash saplings received by a nursery in southern Prince George's County (Maryland Department of Natural Resources [MDNR] 2007). Nursery records and regulatory investigations conducted by the USDA and the Maryland Department of Agriculture (MDA) revealed that 121 ash nursery stock were received in two shipments from Michigan in April 2003. On 28 August 2003, during a routine inspection at the nursery, an MDA nursery inspector discovered several ash trees with diagnostic D-shaped exit holes and bark splits with serpentine galleries beneath, that resulted from adult EAB emergence earlier in the spring (MDA 2006). One ash sapling was taken to the MDA in Annapolis, Maryland, and debarked, and several suspect larvae were recovered. Initially identified by Gaye L. Williams, MDA Entomologist, the larvae were then sent to the Systematic Entomology Laboratory (SEL) at the USDA Agricultural Research Service (ARS) facility in Beltsville, Maryland, for confirmation. On 29 August 2003, the specimens were positively identified as EAB by Robert W. Carlson, SEL Entomologist. The specimens remained at SEL.

Following confirmation of the larvae as EAB, an intensive quarantine and eradication program was immediately initiated. The MDA destroyed all 442 ash trees that were currently in-stock at the nursery, located and destroyed over 170 ash trees the nursery had out-planted since receipt of the infested ash from Michigan, and additionally destroyed all ash within a 0.8 km (0.5 mi) buffer zone that was established surrounding the nursery. In total, an estimated 1100 potentially infested ash trees were removed and destroyed on 202 ha (500 ac) of public and private land. In spite of the MDA's program of aggressive delimiting surveys and the destruction of all healthy and infested ash trees found in the quarantine zone, EAB continued to spread in Maryland and by 2008 it was discovered to

Figure 1. ***Agrilus planipennis*** **Fairmaire.** EAB adult resting on an ash leaf.

Figure 2. ***Agrilus planipennis*****.** EAB larvae, early and late instars.

Figure 3. EAB larval gallery in an ash tree. Frass-packed, serpentine trails are typical.

have crossed into Charles County. From 2003 to 2008, based on positive EAB detection data provided by the MDA, it was determined that EAB spread on average approximately 1 km (0.6 mi) per year in Maryland (Sargent et al. 2010). By the end of 2009, approximately 42,000 ash trees on 6880 ha (17,000 ac) from an area of 47.4 km^2 (18.3 mi^2) had been removed and destroyed. At that point, the Maryland EAB program shifted from eradication to inventory and delimiting surveys, investigation of insecticide options for treatment of ash trees, and releases of EAB parasitoids within the infested zone (MDA 2009). By August 2011, EAB had been detected in four more Maryland counties (Allegany, Anne Arundel, Howard, and Washington) and the District of Columbia (Paul Chaloux, National Policy Manager, EAB Program, USDA, Animal and Plant Health Inspection Service [APHIS], Plant Protection and Quarantine [PPQ], Riverdale, Maryland, in litt. 24 October 2011), and the state EAB quarantine was expanded to include all counties west of the Chesapeake Bay. In 2012, EAB was additionally found in Garrett, Montgomery, and St. Mary's, Counties, as confirmed by James E. Zablotny, National EAB Identifier, USDA-APHIS-PPQ, Romulus, Michigan. These specimens remained with Zablotny in Michigan.

With EAB firmly established in several states, including Maryland, focus has shifted from eradication to management and consideration of the risks of infestation and options for managing those risks. Potential losses are significant. The USDA-FS estimates that roughly 9 billion ash trees reside in the continental United States (Patrick D. Miles [Research Forester] via Susan J. Crocker [Research Forester] in litt. 19 March 12:34:45 CDT 2013. Forest Inventory EVALIDator web-application version 1.5.1.04. St. Paul, MN: USDA-FS, Northern Research Station. Available on the internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp). An estimate of compensatory values made in 2003 places the benefits of these ash trees at about $300 billion (Nowak 2003). A recent estimate of EAB management on developed land in the 25 states currently infested or likely to become infested with EAB found that the treatment, removal, and replacement costs for the 17 million ash trees in such locations will exceed $10.7 billion over a 10-year horizon (Kovacs et al. 2010). Ash species account for a relatively small proportion of native forest trees in Maryland, but white ash and green ash have been among the most heavily planted landscape tree species in this state's urban forests. In 2001, a pilot survey of street trees in Maryland estimated that there were 643,958 (+/- 9%) street trees in the state, of which 3% were *Fraxinus*, placing it among the ten genera most frequently found along Maryland's urban roadways (Cumming et al. 2006). This translates into roughly 19,000 ash trees lining Maryland's streets. A survey of trees on multiple land use types in the City of Baltimore and the surrounding Urban-Rural Demarcation Line (URDL) revealed ash to be one of the most common trees with more than one-half million ashes in this densely populated area (Nowak et al. 2009). The impact and costs of EAB infestation will be significant in Maryland, and municipalities should begin planning now to budget for and develop management options to deal with this destructive pest.

To assist urban foresters, planners, landscape managers, and private citizens in understanding the potential impact of EAB on Maryland's urban forests, we conducted the following research with three goals. First, we developed models to understand how

rapidly EAB moved from its initial introduction site in Prince George's County to surrounding locations. Second, we demonstrated a methodology for estimating the economic and ecological benefits of ash trees in cities. Finally, we developed a heuristic approach for estimating the costs of managing EAB in cities under different management scenarios. With this information, we hope to help guide municipal administrators in developing pro-active plans for managing EAB in Maryland's urban forests before the arrival of EAB.

MATERIALS AND METHODS

Knowledge of the dispersal rate of EAB over time enables us to predict when the pest may arrive in locations beyond the original point of introduction, and provides a timeframe for municipalities to prepare a management plan in the event of infestation. To determine the potential impact on a municipality due to EAB infestation and the resultant loss of ash trees, it is necessary to know the number and size (diameter at breast height [DBH] in inches, 1.4 m [4.5 ft] above the ground) of ash street trees in the community. With this information, software programs can then be used to estimate the dollar costs for different management options as well as the values of ecological benefits lost should trees require removal. All of these tools combined help us estimate the risk of potential infestation and the resultant impact on Maryland communities.

Rate of spread of EAB in Maryland

The MDA collected spatially explicit data from 2003 to 2010 on positive detections of EAB from naturally-occurring and managed ash trees in landscapes. Positive detections were initially based on the presence of EAB exit holes and active galleries in debarked trees, and then confirmed by the recovery and identification of larvae found in the tree. These specimens are held at the MDA in Annapolis. The rate of spread of EAB in Maryland was initially investigated by analyzing EAB detection data provided by the MDA for 2003 through 2008 (Sargent et al. 2010). There were no additional positive detections from the first report of EAB in Prince George's County in 2003 through 2005, but in 2006 EAB was again detected. By 2008, thousands more detections had been confirmed within the quarantine zone surrounding the nursery where the infested ash stock had been introduced. Using the nursery as the center point, measurements were determined for the four farthest positive EAB detections as an estimate of the leading edge of the beetle's dispersal for each of the three years. The rate of spread was quantified by regressing the distance from the introduction site against time, producing a linear model with an average annual rate of spread of 1.00 km (0.6 mi) and a maximum rate of spread of 1.37 km (0.9 mi) (Figure 4). (See Sargent et al. [2010] for a full description of methods and results.)

In 2010, the rate of spread of EAB in Maryland was re-evaluated using detection data for 2009 and 2010 provided by the MDA (Martinson et al. 2011a). Again we used the four farthest detections for each year from the original point of EAB introduction, and we quantified the rate of spread by regressing distance from the introduction site against time. We evaluated the linear average rate of spread model of Sargent et al. (2010) with

the new detection data to determine if EAB was still advancing from its point of introduction at a constant rate. We also compared the fit of the linear average rate of spread model to that of a polynomial, or increasing, rate of spread model.

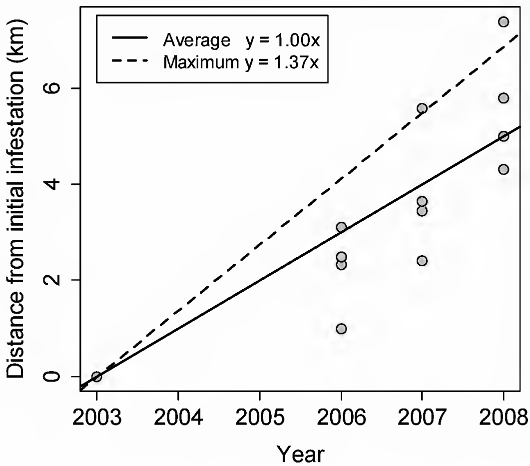

Figure 4. Linear Regression Models of EAB Rate of Spread in Maryland, 2003-2008, from time of initial detection in 2003. Average rate of spread of the leading edge (solid line) was based on the four most distant EAB detections for each year in 2006, 2007, and 2008. Maximum rate of spread (dashed line) was based on the single most distant EAB detection in each year. Fitted lines are linear least square regressions. Modified from Sargent et al. (2010).

Municipal tree surveys and ash benefit assessment

Efforts to obtain existing street tree surveys from several municipalities in the region revealed that few of them actually had surveys, and those that did, had surveys which did not necessarily contain the information required for effective EAB planning and management. We therefore decided to hire and train University of Maryland undergraduate students in the use of i-Tree Streets v.3.0, a free software tool developed by the USDA-FS and numerous cooperators to inventory and assess the benefits of urban street trees (USDA-FS et al. 2009). A complete street tree inventory provides much more comprehensive information about an urban forest, but a random sample survey is quicker, less expensive to conduct, and provides adequate baseline data for planning management strategies. Consequently, we decided to conduct random sample street tree surveys for select Maryland municipalities. Municipal administrators in four communities surrounding the quarantine zone that were most likely to become infested by EAB (Upper Marlboro, Greater Upper Marlboro, Bowie, and Annapolis) were contacted and agreed to participate in the project.

Four undergraduate students were hired and trained in tree identification, the use of i-Tree Streets survey software, and field hardware, including HP iPAQ 210 Enterprise® handheld palm computer (personal digital assistant [PDA]), and DBH tapes. Random street segments were generated for each town using ArcMap 9.3® (ESRI, Redlands, California), a component of the ArcGIS suite of geospatial processing programs. Following i-Tree Streets survey protocols, we randomly selected 4-6% of all possible street segments in each municipality for surveying to conform to the recommended 10% standard error. Street trees were defined as any tree managed by a municipality and planted on city property as determined by its location (a) between the road and the sidewalk, (b) within 3.0 m (10 ft) of the road if there was no sidewalk, (c) between the road and utility poles or structures, (d) on medians or islands within the roadway, or (e) if a uniform row of a single tree species was planted along a street. In cases of uncertainty, a tree was not considered to be an urban street tree if (a) it was located more than 3.0 m (10 ft) from the road, (b) it was surrounded by a fence or other property barrier or was located in a backyard, or (c) a property owner claimed to have planted the tree. Tree diameters were measured in inches at 1.4 m (4.5 ft) above the soil line with DBH tapes and the data entered into a range of DBH size categories as required for analysis in the Purdue EAB Cost Calculator (Sadof 2009): 0-3, 3-6, 6-12, 12-18, 18-24, >24 inches (0-7.6, 7.6-15.2, 15.2-30.5, 30.5-45.7, 45.7-61.0, >61.0 cm).

Surveys in the four communities were conducted in 2010 and 2011. Data were recorded in a PDA in the field, later downloaded into i-Tree Streets, and then used to estimate the total number of municipal ash trees by DBH category in each jurisdiction. We summarized the street tree data and generated reports on the estimated environmental and aesthetic contributions of the trees using the Benefits-Costs Analysis program in i-Tree Streets. This program assigns regional benefits values for urban trees using a representative city in each region to derive appropriate area values. Although regional benefits values are available for each of the most commonly planted trees in the representative city, less commonly used trees are assigned values based on species of similar morphology (e.g., medium deciduous trees). In i-Tree Streets, benefits values of ash are specifically assigned in the Northeast Zone, but not yet in the South Zone where the Maryland municipalities are located. To accurately reflect the benefits provided by urban ash in the Mid-Atlantic region, we selected the Northeast Zone when defining the Climate Region field prior to downloading our survey data into i-Tree Streets for analysis. This enabled us to estimate the ecological benefits provided by ash in these municipalities; Maryland arborists interested in using i-Tree Streets to estimate the value of ash in their street trees would also need to select the Northeast Zone for their analyses.

Management options for ash in the urban canopy

Several decision making models are available for evaluating the economics of management approaches for EAB (Sadof et al. 2011; Vannatta et al. 2012). We chose to use the model developed by Sadof et al. (2011) to demonstrate how communities could evaluate costs associated with managing EAB. Data on the ash tree population by DBH categories for the three municipalities that had ash were entered in the online Purdue University EAB Cost Calculator (Sadof 2009) to generate various management options

and associated costs. By examining the ash tree population data from the municipal ash tree surveys, we were able to assess the scope of the potential risk and impact of EAB infestation for a collection of representative cities in central Maryland.

RESULTS

Rate of spread of EAB in Maryland

The linear average rate of spread model reported by Sargent et al. (2010) for data collected in 2006-2008 under-predicted the leading edge of dispersal of EAB in 2010 (Figure 5, solid line). By 2010, all of the four most distant EAB detections were located above the line predicted by the linear average rate of spread model, indicating that EAB were no longer moving at a constant speed. Because the linear regression model failed to account for the increased rate of expansion of EAB in recent years, we evaluated the fit of a polynomial regression as well, including the effects of year and year^2 on the distance from the initial infestation. The squared term of the polynomial regression was significant ($P = 0.016$), and the polynomial model provided a good fit to the data ($R^2 = 0.958$) and more normal residuals (results not shown), providing evidence for an increasing rate of spread beginning in 2010 (Figure 5). Using the polynomial rate of spread model, we predicted that EAB would arrive in the District of Columbia and Greater Upper Marlboro in 2013, Bowie in 2017, Annapolis in 2021, and Baltimore in 2022.

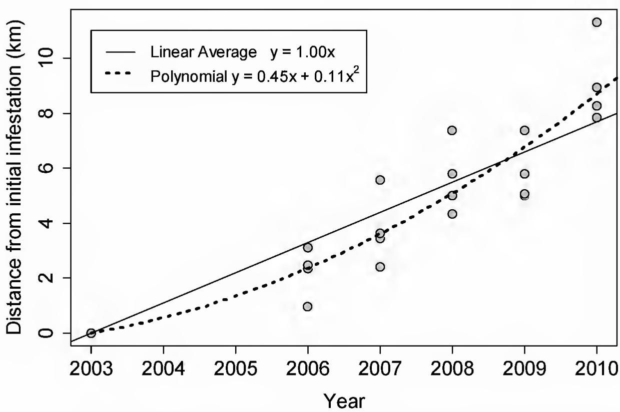

Figure 5. Assessing Models of EAB Rate of Spread in Maryland, 2003-2010: Linear Regression Average Rate (solid line, 1 km/year [0.6 mi/year]); Polynomial model (dashed line, increasing over time).

Municipal tree surveys and ash benefit assessment

The i-Tree Streets estimates for the number and size class distribution of ash trees across the four Maryland municipalities are presented in Table 1. The municipalities included in this project differed greatly in the size of their city-managed ash populations. For example, the small municipality of Upper Marlboro was estimated to have no city-managed ash. Although it is possible some ash street trees do exist in Upper Marlboro, a random sample survey sometimes may not reveal specific tree species, particularly in smaller communities. On the other end of the scale, Annapolis was estimated to have 2,146 city-managed ash trees.

Table 1. Estimated ash population and DBH classes using i-Tree Streets for public street trees in local municipalities. Data are for all ash species combined.

	Diameter at Breast Height (inches)						
Municipality	**0-3**	**3-6**	**6-12**	**12-18**	**18-24**	**24+**	**Total**
Annapolis	787	644	429	238	24	24	2,146
Bowie	0	0	0	0	43	86	129
Greater Upper Marlboro	0	132	314	149	0	0	595
Upper Marlboro	0	0	0	0	0	0	0

Next, using the estimates of the DBH size-class distributions and total numbers of municipally-managed ash trees for each town, we evaluated the benefits provided by ash street trees in Annapolis, Bowie, and Greater Upper Marlboro using the i-Tree Streets Benefits-Costs Analysis program. This program quantifies an estimate of environmental and other benefits provided by the urban forest on an annual basis, assets which are lost to a community if trees are destroyed and removed. Table 2 presents the estimated annual benefits, expressed in dollars, provided by ash trees in the urban canopies of each town for which we had positive ash population numbers. i-Tree Streets v. 3.0 defines "Energy" as savings through conservation (reduced natural gas and electric use and generation); "CO_2" is the reduction in atmospheric CO_2 through sequestration by trees and reduction of power plant emissions; "Air Quality" quantifies air pollutants deposited on tree surfaces, combined with reduced power plant emissions; "Stormwater" refers to runoff abatement due to rainfall interception by trees; and "Aesthetic" represents tangible and intangible increases in property value.

Table 2. Estimated annual benefits (in dollars, rounded to the nearest hundred) of municipal ash street tree populations, calculated in i-Tree Streets. (Note: All street tree values were assessed using the Northeast STRATUM climate zone.)

	Annual Benefit (dollars)					
Municipality	**Energy**	**CO^2**	**Air Quality**	**Stormwater**	**Aesthetic**	**Total**
Annapolis	51,800	900	8,700	10,200	81,200	152,800
Bowie	15,300	400	3,100	4,300	9,000	32,100
Greater Upper Marlboro	25,900	500	4,300	4,900	25,500	61,100

Management options for ash in the urban canopy

The final step in our research was to assess the management options and associated costs that urban forest managers can consider in preparation for the arrival of EAB in their communities. Municipalities have a number of potential strategies for managing their ash populations using the options available in the Purdue EAB Cost Calculator (Sadof 2009), which takes into consideration the cumulative costs of ash management over time. To demonstrate only a few of the options available, we estimated the 5- and 25-year cumulative costs of five different management options for the three towns in which street ash were found. Cities have the choice of treating all of the ash the same within a chosen strategy, or, alternatively, may consider a number of hybrid approaches in which they treat certain trees and remove or replace others. We chose to consider the following different options: (1) remove all ash trees without replacement; (2) remove and replace all ash with non-susceptible species; (3) treat all ash trees yearly with insecticides; (4) remove and replace all ash trees < 24 inches DBH and treat all ash > 24 inches DBH (assuming large trees can be effectively treated) so that the benefits provided by large trees are retained in the urban canopy (Kovacs et al. 2010). We also looked at a combined strategy (5) called Urban SLAM (SLow Ash Mortality) (Sadof 2009), a citywide plan which quantifies costs for all urban trees, both public and private. This strategy involves the application of the insecticide TreeAge® to 40% of randomly selected ash trees in a municipality, with 20% treated each year, through year 12 when the wave of EAB invasion is likely to have passed. Urban SLAM offers a cost effective method predicted to protect up to 99% of ash trees in an urban forest. Choosing to use Urban SLAM would require a survey of all ash trees in a city, not just street ash trees. Nonetheless, we included the Urban SLAM model in our analysis for heuristic purposes. Default values for treatment costs were $3/inch DBH treated annually; replacement costs were $400/tree; removal costs ranged from a cost of $11.15/inch DBH for small trees (< 6 inches DBH) up to $25/inch DBH for large trees (> 24 inches DBH), and removals were conducted over a 7-year period. All calculations assume a 2% ash mortality rate, a 2% replacement mortality rate, and a discount rate of 0% (Table 3).

Table 3. Estimated cumulative costs (in dollars, rounded to the nearest thousand) of management options for ash tree populations, over 5- and 25-year periods, calculated with the Purdue EAB Cost Calculator 2.0. Presented are five illustrative management options: Remove all ash trees; Replace all ash trees with non-ash species; Treat all ash trees annually; Replace ash trees < 24 inches DBH and treat those >24 inches DBH; and Urban SLAM.

		Estimated Cumulative Cost (dollars)				
Municipality	**Yr**	**Remove All**	**Replace All**	**Treat All**	**Replace <24”**	**Urban SLAM**
Annapolis	5	124,000	612,000	149,000	602,000	54,000
	25	228,000	1,082,000	924,000	1,081,000	298,000
Bowie	5	44,000	72,000	18,000	36,000	8,000
	25	82,000	132,000	124,000	123,000	46,000
Greater Upper Marlboro	5	48,000	184,000	43,000	184,000	17,000
	25	100,000	338,000	294,000	338,000	97,000

DISCUSSION

An important first step in developing plans to mitigate the impact of an invasive species is to determine how quickly it spreads. The National EAB Science Panel, following the best scientific guidelines available at the time, recommended to the MDA in 2003 that removing all ash within a 0.8-km (0.5-mi) zone beyond known positive detections of EAB should eradicate the insect. Sargent et al. (2010) reported an average spread of 1 km (0.6 mi) and a maximum rate of spread of 1.37 km (0.9 mi) per year in Maryland. With the knowledge that EAB were spreading faster in Maryland than had been expected, the MDA in 2009 adjusted its response from a program of eradication to one of slowing the spread, with an emphasis on researching biological control organisms and chemical treatment of high value ash trees.

Analyzing EAB detections from naturally-occurring and landscape ash trees around the original point of EAB introduction to Maryland, we demonstrated an increasing rate of spread in recent years for this beetle (Figure 5). Using this polynomial rate of spread model we estimated that EAB would arrive in the municipalities closest to the original point of introduction by 2013. Confirmed EAB detections in the District of Columbia in 2011 are within the confidence intervals for this model and consistent with our assessment of an increasing rate of spread. In Michigan, Siegert et al. (2008) demonstrated that the spread of EAB has two phases: an early one in which beetles spread relatively slowly, and a later rapid phase in which beetles may spread more than 19.3 km (12 mi) each year. Based on the arguments of Siegert et al. (2008) and our own analysis, we would expect further increases to the rate of spread of EAB in Maryland. Indeed, trapping and survey data from 2011 revealed an even faster rate of spread than was detectable based on the 2010 data, as well as additional EAB foci distant from the original site of introduction in southern Prince George's County. These newer foci likely represent spread from adjacent states or human-assisted movement of EAB, such as through the movement of firewood (Tobin et al. 2010). Regardless of the means of spread, the annual rate of advancement of the leading edge of EAB is clearly accelerating rather than remaining constant.

In light of the evidence for an increasing rate of spread and possible secondary introductions of EAB in the area of the state west of the Chesapeake Bay, we suggest that municipalities begin planning for the arrival of EAB. Martinson et al. (2011b), offer a convincing argument that any municipality in a state with a known EAB infestation should start making plans now to manage their ash tree population. It is incumbent on municipalities to protect their citizens from risk of injury and loss due to downed trees and branches, and to budget for those activities accordingly. Knowing approximately when EAB might reach their boundaries gives urban arborists a valuable tool when requesting funding and support from municipal governments to develop and implement EAB management strategies. Cities located farther from the initial point of infestation in southern Prince George's County or newly discovered sites in Anne Arundel and Howard Counties may have more time to develop best management solutions prior to infestation, but it would appear that infestation is inevitable.

The most basic requirement for developing plans to manage the consequences of EAB infestation is to determine the number and size of ash trees in a community. If a recent tree survey does not exist, urban foresters would be wise to conduct one now. Assessments can be conducted for street tree populations using i-Tree Streets. Designed to be flexible and readily adapted to the individual needs of any community, i-Tree Streets is not GIS-based and requires only basic tree data. Assessment of street trees is relatively easy, in part due to the ease of accessing street trees. Using i-Tree Streets, a random street segment survey can be quickly carried out to estimate the number of ash trees, or more time can be invested in a complete survey that will count and locate every ash street tree within municipal boundaries. Additionally, a city might choose to focus on surveying a single species, such as ash, or may opt instead to conduct a survey of all tree species in the urban canopy to provide a valuable tool for future management of all trees. i-Tree Streets gives users the flexibility to consider only a few parameters about their urban canopy, such as the number and size of ash trees, or many parameters, such as tree condition and site conflicts (e.g., sidewalk damage and overhead wire obstruction), thus providing a valuable management tool for all street trees. The decision to conduct a complete survey or a random sample survey of street trees will be based in part on how soon EAB will arrive in a community, and how much time is available to prepare.

With the data from a complete or random sample ash tree survey, planners may utilize a number of report options available in i-Tree Streets to calculate the estimated environmental benefits provided by ash trees in their communities. The benefits of existing ash should be taken into consideration prior to making management decisions about their treatment or removal. Ash trees contribute both environmental and structural value to a community, and there is also growing evidence that healthy natural environments contribute significant public health benefits for residents as well (Donovan et al. 2013). Ash street trees in the three Maryland communities we surveyed contribute over $246,000 each year in environmental benefits to those municipalities. These benefits and the associated monetary value are lost with the destruction and removal of ash from the urban canopy. Structural value is based on the cost of having to replace an existing street tree with a similar tree, and takes into account the number of trees, species, tree size, condition, and location. The structural value of an urban forest tends to rise with an increase in the number and size of healthy trees. For example, white ash ranks seventh among the ten most valuable tree species within the nearly 53,014 ha (131,000 ac) of highly urbanized real estate surrounding the City of Baltimore, and provides about $345 million in structural value (Nowak et al. 2009). Structural value of ash trees in the City of Baltimore is estimated at an additional $199 million, and in the District of Columbia, it is estimated at $88 million. Knowing the benefits and structural value of the existing ash trees in an urban forest will help guide urban foresters in decisions on how to manage them.

Finally, urban foresters have a number of management options available at this time to assist them in preparing for the arrival of EAB. In our study, the DBH class data from each survey were analyzed in the Purdue University on-line EAB Cost Calculator (Sadof 2009) to assess the economic impact of EAB infestation on each community, and to consider the different management options available. Larger trees produce proportionally

more ecological and structural benefits to the urban canopy than do small trees. We chose to look at five management options that would take into consideration a variety of scenarios. Overall, removing ash without replacement was typically less expensive than all but the Urban SLAM option, but leaves the municipality with a reduced urban canopy cover and the dramatic loss of associated environmental and aesthetic benefits. For example, in Annapolis the cost of removing all ash over a 5-year period would be an estimated $124,000, but the cumulative annual benefits lost over that same period of time would equal approximately $764,000. Replacement was the most expensive option, combining the costs of both tree removal and replacement. Treating trees yearly over 25 years is an expensive option, but would leave the entire urban canopy and associated benefits intact and have consistent annual costs. Assuming large trees can be effectively treated with insecticides, the hybrid strategy of treating large (>24 inches DBH) and replacing small and medium sized ash trees costs less than replacing all trees, and leaves more canopy intact. Finally, the experimental approach known as Urban SLAM provides a potentially cost-effective strategy to retain ash trees and their ecological benefits in the entire urban canopy until the wave of EAB spread has passed. The optimal management strategy will have to be selected by municipalities in light of their budgets, their ash population sizes, the tree benefits they hope to preserve, and the estimated time they have to implement plans prior to the arrival of EAB.

CONCLUSIONS

The Emerald Ash Borer is a threat to all native ash trees, and the urban ash populations in local municipalities must be managed. The overall risk to a municipality will be a function of the time to arrival of EAB, the number and size class distribution of their ash population, and the environmental and aesthetic benefits of ash in their urban canopy. To assess both risk and economic benefits, cities can conduct street tree inventories and estimate ash tree population sizes with the i-Tree Streets program. To assess economic impact, municipal arborists can then use tools available in the Purdue University EAB Cost Calculator to determine timely and effective management programs with associated annual and cumulative estimated costs that best serve their communities. City managers and planners, urban foresters, and other decision-makers can combine dispersal information with benefits loss and management costs to identify the potential risk of EAB infestation, and the resultant economic and environmental impacts on their municipalities. They will have the information and tools necessary to prepare budgets, develop comprehensive Integrated Pest Management (IPM) programs, and plan activities to deal effectively with EAB and to better manage municipal forests. Regionally, EAB will be very expensive to municipalities, but the time prior to infestation can be used to prepare management plans to help mitigate the losses, both financial and ecological.

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Records of *Prateus fusculus* LeConte (Coleoptera: Tenebrionidae) in Maryland and West Virginia, with Observations on Habitats and Known Distribution

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ABSTRACT: An obscure rarity in entomological collections, *Prateus fusculus* LeConte (Coleoptera: Tenebrionidae) has been known from scant and scattered localities in the eastern United States. New distribution records are presented here, with specimens identified from several eastern states and northeastern Mexico. Noteworthy Maryland and West Virginia collections provide information on the biology of this species of mature forests.

INTRODUCTION

Prateus fusculus LeConte (Coleoptera: Tenebrionidae) is a small (3.0-3.7 mm [~ 0.1 in]), elongate, tan-colored darkling beetle in the subfamily Lagriinae Latreille. It is generally rare in collections, and very little is known about its biology. Widespread in the southeastern United States, it is the only member of the tribe Lupropini Ardoin in North America, but the group has a pan-tropical distribution (Matthews et al. 2010). It is currently the only described member of its genus, but undescribed species from Central and South America and the Antilles are known in collections.

The dorsum of the beetle (Figure 1) is shining, confusedly punctate, and the pronotum has a narrow marginal bead that is slightly undulate in most specimens. The last three antennomeres are slightly enlarged to form a weak club (Figure 2). Males have a small median oval concavity bearing a patch of fine hairs on the first abdominal ventrite (Figure 3). Wings are fully developed.

Prateus fusculus has been listed as occurring in Maryland (Steiner 2008) but no details were provided; this record is substantiated here by the specimen data presented below, and new information on habits and habitats of the species is given. Its discovery by the author at Shepherdstown, West Virginia, was described by Wennerstrom (1996) in a popular book on the human and natural history of the upper Potomac River valley.

KNOWN DISTRIBUTION RECORDS

Distribution records in the literature are few, and information on habitats is even scarcer. In a brief diagnosis of the genus and species, LeConte (1862) stated that it was found "in the Middle and Southern States" but with a more formal description, published four years later, the type-locality is given as "New York" (LeConte 1866). Horn (1870) added South Carolina, stating that "it probably occurs everywhere in the Atlantic region, though

Figure 1. *Prateus fusculus* LeConte, dorsal view. Length of beetle, 3.4 mm (0.13 in).

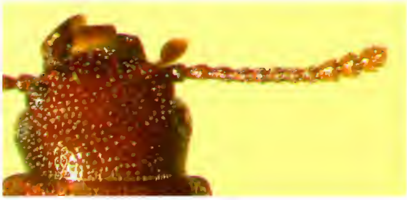

Figure 2. *Prateus fusculus*, dorsal view of head and right antenna. Length of antenna, 0.9 mm (0.04 in).

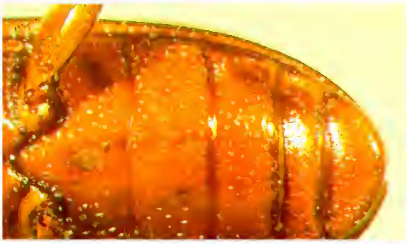

Figure 3. *Prateus fusculus*, male, ventral view of abdominal ventrites showing oval patch of setae in middle of first ventrite. Length of abdomen, 1.2 mm (0.05 in).

rare." Schwarz (1878) reported the first Florida record, repeated in subsequent lists, for "one specimen under old leaves" and gave no specific locality, but one specimen in the United States National Museum of Natural History (USNM), Smithsonian Institution, labeled "Tampa 2-4 Fla / Coll Hubbard & Schwarz" is probably the voucher for this record. Recently, an image of a specimen taken in a light trap in Clay County, Florida, has been posted on BugGuide (Garrison 2011). Blatchley (1910) stated that *P. fusculus* "ranges from New York to South Carolina and has been recorded from Cincinnati." The Ohio occurrence was listed by Dury (1902). The District of Columbia record of Ulke (1902) adds "in rotten wood, rare." In South Carolina, a specimen was found "in hollow tree" (Kirk 1969). A recent eastern Tennessee record from Blount County has been posted by the Louisiana State Arthropod Museum (2006).

SPECIMENS EXAMINED

The following specimens in USNM, unless otherwise noted for Ohio State University Collection (OSUC) and Mississippi Entomological Museum Collection (MEMC), add

new distribution records that expand the known range considerably, and associated notes add some biological information on this rare insect. Label data are for the most part given verbatim, with commas inserted for clarity; inferred parts of abbreviated dates and names are bracketed, and breaks between labels are separated by a forward slash.

District of Columbia record:
"Washington D.C., 8-5 [8 May] / Coll Hubbard & Schwarz" (1).

Maryland records:
"MARYLAND: Calvert Co., Calvert Cliffs St. Pk., 5 km. SE Lusby, 5 March 1983, W. E. Steiner / Under bark of rotting stump of *Liquidambar*" (5); "MARYLAND: Montg[omery]. Co., Seneca, 24 Feb. 1974, W. E. Steiner / Under loose bark of dead standing *Ulmus americana* in mixed forest near stream" (1); "MARYLAND: Pr[ince]. Geo[rges]. Co., Cheverly, "38°56'N, 76°55'W, 18 June 1993, W. E. Steiner & J. M. Swearingen / At black light at ground level, mixed broken forest and residential area" (1); same data except "25 June 1999 / At black light in tree canopy, mixed broken forest and residential area" (1); same data except "15 June 2009" (1); "MARYLAND: Q[ueen]. Anne's Co., Carmichael, 2 Oct. 1973, W. E. Steiner / In dry pithy wood of large fallen trunk *Liriodendron*" (1); "MARYLAND: Talbot Co., St. Michaels, 28 May 1990, W. E. Steiner & J. M. Swearingen / In soft dry rotten wood lining hollow trunk of live *Liquidambar*, with carpenter ants" (14); same data except "38°47'N, 76°14'W, 16 February 1992" (1) and "8 Nov. 1992" (7); "Takoma Park, Md, XII-2 '[19]50, D G Kissinger" [county not determined; may be either Montgomery or Prince Georges] (1).

Additional habitat information from field notes:
The 1983 Calvert County record was from along a trail in mixed forest: "near swampy drainage, spent time picking at a rotting trunk of sweetgum broken off about 8 feet up—3 good catches (tenebs.) under bark, including series of 5 *Prateus* and a *Pentaphyllus* under surprisingly dry and fairly tight bark about 4-6 feet above ground, in small galleries with fine frass."

At the St. Michaels site, 28 May 1990, the host tree was found in a mixed forest tract with old white oaks (*Quercus alba* L. [Fagaceae]), loblolly pines (*Pinus taeda* L. [Pinaceae]), and other trees, with low wet areas: "Into forest deeper & came to an old sweetgum, the base of which was an open, boat-like half shell. From one side the tree appeared perfectly whole & solid; from the other, it seemed impossible that the tree was still alive & standing—80-90% of the trunk mass was hollowed out, & this went up the leaning trunk for some distance. Basal hollow was somewhat of a rain shelter & had chunks of dry rotten wood still attached to back wall—broke off some of this to expose an active nest of *Camponotus* in ornately riddled wood. In newly exposed hollows & crevices (made by but not now inhabited by the ants) found 3 single specimens of *Prateus fusculus*…" and "more came out later from chunk of riddled wood kept in plastic bag; 14 adults and a few assoc. larvae." The two visits to the same tree in 1992 yielded more specimens with the final collection on 8 November: "took more riddled wood from the hollowed sweetgum where *Prateus* was found; picked over it later & got another good series of *P. fusculus* adults, & small cossonines, alleculine larvae, &

pseudoscorpions." Three specimens of the associated carpenter ants from the first collection have been identified as *Camponotus chromaiodes* Bolton (Hymenoptera: Formicidae), known to be widespread and common in Maryland (Timothy Foard, pers. comm.).

The three single specimens taken at black lights in Cheverly, Maryland, 1993-2009, were each collected on warm nights (25°, 24°, 23°C [77°, 75°, 73°F] at dark, respectively) with high humidity noted, after sunny to partly sunny days with no precipitation and afternoon high temperatures of 29-33°C (84-91°F). Beetles were collected by hand from white linen sheets; the June 1999 specimen was noted as being taken at dusk.

West Virginia records:

"WEST VIRGINIA: Jefferson County, Shepherdstown, 39°26'N, 77°48'W, 17 April 1994 / In soft dry rotten wood lining hollow trunk of live *Acer negundo* / W. E. Steiner, J. M. Swearingen et al. collectors" (8); same data except "21 April 1996" (1) and "28 March 1999" (3). A small sample of the wood with the same data is associated.

Additional habitat information from field notes:
The site of these collections is on the sloped flood plain of the Potomac River. In notes for the 1994 discovery: "Picked at some rotten dry wood lining a half-shell trunk of boxelder, & exposed a few *Prateus fusculus* in galleries between the pithy loose wood and solid inner wall, now sunlit from the west, down along creek bank; at least 2 larvae associated also." The same tree was examined two years later and was found to have been partly flooded (with mud deposited in the lower part of the hollow) and very little loose pithy wood remained at the upper rim, but one beetle was found there. In March 1999, the tree was found broken over with "not much remaining of the hollow trunk…but picked at a 2nd tree up on higher ground & found more—3 adults & more frags. in layer of pithy wood lining the dry inner treehole wall; the trunk base entirely hollow & open." Both adults and larvae were in tunnels (0.7-1.3 mm [0.03-0.05 in] in diameter) in the pithy wood, running with and across the grain.

Other records:

Alabama: Three collections from Alabama (MEMC) represent the first known records for that state: "ALA., Cleburne Co., Talladega Natl. Forest, 33°33'30"N 85°42'35"W, 19 May 1998, J.A. MacGown / blacklight & M.V. lamp in burned area in mixed forest, W. H. Cross Expedition" (1); "ALA., Lawrence Co., Joe Wheeler St. Park, 34°47'09"N 87°23'16"W, 27 May 2004, T. L. Schiefer / Blacklight in mixed forest, W.H. Cross Expedition" (6); "ALA., Monroe Co., Haines Island Park, 31°43'23"N 87°28'10"W, 24-25 July 1995, T. L. Schiefer, Blacklight Trap" (1).

Arkansas: A new state record for Arkansas is substantiated by a specimen in OSUC: "Arkansas, Little Rock, VII-16-17-2002, Brian Baldwin (black light trap)" (2).

Florida: A second Florida specimen is from a northern part of the state: "2 Mi S. Durbin VI.5.1952 Fla D G Kissinger / Beating."

Mississippi: Several new Mississippi state records (MEMC and OSUC) bear habitat information: "MISS., Lowndes Co., T17N, R16E, Sec. 34, 19 June 1991, D. M. Pollock,

Blacklight Trap" (1); "MISS., Oktibbeha Co., Starkville, T18N, R14E, Sec. 2, 22 April 1991, T.L. Schiefer / Berlese of bark of dead *Celtis laevigata* covered with fungus" (10); "MISS., Oktibbeha Co., Starkville, T18N, R14E, sec. 2, 30 April 1991, T.L. Schiefer, em. 4-6 May 1991 ex dead *Celtis laevigata* covered with fungus" (1); "MISS., Winston Co., Tombigbee Nat. Forest, 33°12'53"N 89°06'10"W, 10 May 1999, T.L. Schiefer, blacklight trap in mixed mesic forest" (1).

North Carolina: One specimen labeled "Rnd. Knob 24-6 NC / Coll Hubbard & Schwarz" is perhaps the first North Carolina record.

Oklahoma: Oklahoma specimens (OSUC) include perhaps the western limit of the known distribution: "OKLAHOMA: Latimer Co., X-1989, Karl Stephan" (7); same data except "III-1990" (1); "Oklahoma [Caddo Co.], Hinton, 26-VII-1966, Karl Stephan" (1).

Tennessee: Additional Tennessee specimens are in OSUC: "TENNESSEE: Knoxville, III-15-16-1955, H. & A. Howden, beech tree hole" (5); "TENNESSEE: [Shelby Co.], Cuba, 25-V-1964, Karl Stephan" (1).

Texas: Three localities in eastern Texas represent new records for that state: "TEXAS, Sabine Co., 9 mi. E of Hemphill, "beach bottom", IV-24-1989, R. Anderson, E. Riley, E. Morris / Berlese *Neotoma* nest from inside dead magnolia trunk" (2, OSUC); "Columbus 27.8 Tex / Hubbard & Schwarz" (1) and "Victoria 14.3 Tex / EASchwarz Collector" (9); one specimen, each with the same data except dates "15.3" and "17.3" hand-written.

Virginia: Also in OSUC is the first known specimen from Virginia: "VIRGINIA, Patrick Co., Reynolds Homestead NE of Critz, VIII-11-18-1970 [no collector given]" (1).

Mexico (Tamaulipas): Lastly, there is a considerable range extension and new country record for Mexico (Tamaulipas): "Tampico Mex 16.12 / EASchwarz Collector" (3), also identified by E. A. Schwarz.

DISCUSSION

Prateus fusculus is now known to occur from New York (exact locality unknown) to southwestern Ohio, south to northern Florida, and west to central Oklahoma and Tamaulipas, Mexico. Collection records indicate that adult beetles hibernate and could probably be found throughout the year in mature forest habitats. Flight dispersal in Maryland occurs in June; dispersal is probably earlier in the southern parts of the range. The few larvae associated in April and May do not offer much information on the life cycle; attempts to rear them were unsuccessful. Immature stages remain to be described.

While some specimens have been found simply under bark of various dead trees, the optimum microhabitat and substrate for colonization by *P. fusculus* appears to be in old, living trees in the pithy dry wood on inner walls of cavities sheltered from rain. Finding trees with this combination of factors is not a frequent event and so is perhaps a reason for the rarity of *P. fusculus* in collections. Larvae of some other Lupropini are known to develop within dead wood (Matthews et al. 2010). The single association with an active ant nest in the same hollow tree is probably incidental; beetles were found in peripheral

wood and not in the *Camponotus chromaiodes* galleries, and *Prateus* has no special adaptations for myrmecophily.

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First Records of Dainty Sulphur, *Nathalis iole* Boisduval (Lepidoptera: Pieridae: Coliadinae), in Maryland

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The small Dainty Sulphur, *Nathalis iole* Boisduval (Lepidoptera: Pieridae: Coliadinae) (Figure 1), is unique among North American sulphurs in several structural features, so much so that some experts feel it belongs in a separate subfamily (Opler and Malikul 1998). For example, unlike other native Coliadinae, the male has a scent patch at the base of the dorsal hindwing cell $Sc+R_1$, which is orange; and the color and pheromone glands are in the wing itself, not in the androconial (scent) scales (Scott 1986).

Figure 1. First Maryland record of Dainty Sulphur, *Nathalis iole* Boisduval. Billingsley Road, Charles County, 19 June 2012. (Photographed by and used with permission of Thomas Ostrowski)

The larval hosts of *N. iole* are mostly weedy composites (Asteraceae) including common sneezeweed (*Helenium autumnale* L.), hairy beggarticks (*Bidens pilosa* L.), and garden marigold varieties (*Tagetes* L. spp.), but laboratory experience also indicates that pink family (Caryophyllaceae) species such as common chickweed, *Stellaria media* (L.) Vill., are utilized. Scott (1986) also includes the introduced exotic green carpetweed, *Mollugo verticillata* L. (Molluginaceae), as an observed oviposition plant, and Miller and Lehman (2012) have confirmed that this is indeed a larval host for *N. iole* from larval studies on a temporary colony of this butterfly species discovered in Washington County, Pennsylvania in August 2012.

If reproductive conditions are favorable, legions of this butterfly advance northward from Mexico and the Chihuahuan Desert region annually. Usually following major river courses, they colonize low weedy locations, breed very rapidly, and by late summer eventually reach as far north as south-central Canada by means of the cumulative travel distances of multiple generations (Pyle 1981). In spite of it annual range extension, the species is unable to survive prolonged freezing and thus dies off in all areas of the continent experiencing such conditions each winter. In spite of this, its Midwestern United States and Canada repopulation spectacle is reenacted year after year (Pyle 1981).

In the East, *N. iole* colonized Florida beginning around 1913, probably from the Caribbean (Opler and Krizek 1984) and flies in Florida year-round. Occurrence of the butterfly has been recorded from June to November along the Coastal Plain of South Carolina and, in 2012, to the northern Piedmont of North Carolina (LeGrand and Howard 2013). Beyond that, and in contrast to its Midwestern United States activity, historical records of the butterfly in the east-central and northeastern United States have consisted only of rare strays (Cech and Tudor 2007). Denise Gibbs, Monarch Watch Conservation Specialist, (pers. comm.) has recorded 2-3 specimens of Dainty Sulphurs, apparently southern coastal strays, during some of the years of her Monarch, *Danaus plexippus* (Linnaeus) (Nymphalidae) migration studies at Chincoteague National Wildlife Refuge, Virginia, in the late 1990s and early 2000s. *Nathalis iole* was never reported in Maryland prior to 2012. The only other historical occurrence close to Maryland was reported first on 24 July 1999 by Curt Lehman in Hardy County, West Virginia in that state's Great Valley physiographic province near the South Branch Potomac River southeast of Moorefield (from "Verified Sightings" data on *Butterflies and Moths of North America* [BAMONA] [Opler et al. 2012]). The reasons for the obvious migrational contrast between Midwestern and eastern United States populations of the Dainty Sulphur are not known.

The year 2012, however, perhaps because of its record-breaking warm March and hot summer, brought a distinct break in the pattern of only rare strays of *N. iole* in the northeastern United States. In this area, reports first surfaced in Mercer County in far northwestern Pennsylvania on 14 June 2012 (posted on Yahoo! Groups listserv "PA Leps and Odes" [http://groups.yahoo.com/group/PaLepsOdes/] by Suzanne Butcher on 16 June 2012). The next report was not until 1 August from Madison County, Virginia near the Shenandoah National Park west of Culpepper by David Cox (posted on Yahoo! Groups listserv "Lepidoptera List [LEPS-L]" [http://groups.yahoo.com/group/leps-l/] on 1 August 2012). At this point, I issued a request on the local Yahoo! Groups listserv "VA-MD-DE-Bugs" (http://groups.yahoo.com/group/VA-MD-DE-Bugs/) for any more records from the Mid-Atlantic region. Just three days later, David Czaplak, a Maryland resident and well-known avian record-reporter, announced a sighting of a Dainty Sulphur on 29 July at the Woodstock Equestrian Park in western Montgomery County, Maryland. On 3 August, Czaplak reported another 6-8 individuals at this same location. For the remainder of the season, and until late October, observers reported multiple sightings of this species from this single site and remarkably from nowhere else in Montgomery County. Harry Pavulaan later discovered large patches of green carpetweed growing in the vicinity of this season-long and apparently successfully breeding "spring-up"

population. However, this Montgomery County location was far from being the only site reporting Dainty Sulphurs in Maryland in 2012. Thomas Ostrowski (pers. comm.) later reported to me what was to become the first Maryland state record for Dainty Sulphur from Billingsley Road in Charles County on 19 June 2012 (Figure 1). First and second known records from Maryland counties are listed in Table 1.

Table 1: First and second known Maryland county records of *Nathalis iole*. 2012.

Date	County	Location and Notes	Observer
June 19	Charles (**1st state record** & 1st county record)	Billingsley Road	Tom Ostrowski
July 29	Montgomery (1st county record)	Woodstock Equestrian Park	Dave Czaplak
August 3	Montgomery (2nd county record)	Woodstock Equestrian Park; 6-8 individuals	Dave Czaplak
August 18	Prince George's (1st county record)	Merkle Wildlife Sanctuary; nectaring on poorjoe (*Diodia teres* Walter)	Mikey Lutmerding
August 20	Calvert (1st county record)	North Beach	Lisa Garrett
September 3	Harford (1st county record)	Eden Mill Nature Center	Richard Smith, Annette Allor, & Nicole Eller
September 3	Prince George's (2nd county record)	Clinton; 6 specimens in a field nectaring on vente conmigo (*Croton glandulosus* L. var. *septentrionalis* Müll. Arg.)	Bill Hubick
September 11	Anne Arundel (1st county record)	Plummer House, Parris N. Glendening Nature Preserve, Jug Bay Wetland Sanctuary	Sue Ricciardi & Dave Perry
October 5	Baltimore (1st county record)	White Marsh Road near White Marsh Mall	Bob Gardner
October 6	Charles (2nd county record)	west end of Liverpool Point Road	Annette Allor
October 24	Carroll (1st county record)	Flag Marsh, Mt. Airy	Dave Smith
October 24	Howard (1st county record)	Columbia Gateway Business Community	Jim Wilkinson
October 25	Howard (2nd county record)	Patuxent Branch Trail, Columbia	Linda Hunt

Surprisingly, no records were ever received or are known from Western Maryland, Maryland's Eastern Shore, or from the state of Delaware.

Further reports of Dainty Sulphur in Virginia in late summer and early autumn of 2012 were announced also, but numbers of locations were fewer than in Maryland. Table 2 summarizes Virginia records that appeared on the Yahoo! Groups listserv "VA-MD-DE-Bugs" in 2012.

Table 2: 2012 Virginia records of *Nathalis iole* appearing on Yahoo! Groups listserv "VA-MD-DE-Bugs."

Date	County	Location	Observer and Date Posted
August 20	Loudoun	Leesburg; 2 specimens, abundant sneezeweed noted in the area	Harry Pavulaan (20 August 2012)
August 27	Rockingham	Elkton; 1 specimen	Mike Smith (28 August 2012)
September 25	Rockingham	Merck; 1 specimen	Mike Smith (26 September 2012)
October 1-5	Accomack	south Assateague Island; "abundant" in some locations	Denise Gibbs (5 October 2012)
October 5	Loudoun	Willowsford in Ashburn; several seen in garden and adjacent low grassy areas	Mona Miller (5 October 2012)
October 5	Loudoun	Willowsford in Ashburn; "dozens" nectaring in community garden	Sheryl Pollock (5 October 2012)
October 5	Prince William	Veterans Memorial Park, Woodbridge; 4 specimens	Sheryl Pollock (6 October 2012)

Two additional Dainty Sulphur records (Table 3) were reported in Virginia on BAMONA (Opler et al. 2012).

Table 3: 2012 Virginia records of *Nathalis iole* reported on BAMONA (Opler et al. 2012).

Date	County	Location	Observer
October 3	(not applicable)	City of Richmond	Naseem Reza
October 11 & 18	Prince William	Veterans Memorial Park, Woodbridge	Matt O'Donnell

One additional Virginia record was reported to the Blue Ridge Center for Environmental Stewardship (Table 4).

Table 4: 2012 Virginia records of *Nathalis iole* reported to the Blue Ridge Center for Environmental Stewardship (H. Pavulaan, in litt.).

Date	County	Location	Observer
October 6	Loudoun	Blue Ridge Center for Environmental Stewardship near Neersville; 1 adult	Harry & Sandra Pavulaan

Most of the Maryland and Virginia sightings were located near Atlantic coastal rivers, in particular the Potomac and Patuxent Rivers, as well as near the Chesapeake Bay, and on coastal Assateague Island. Although movement across the Appalachians from the western population is a likely explanation for many of the eastern United States records of Dainty Sulphur in 2012 (H. Pavulaan, in litt., 25 June 2013), these latter locations could indicate some influx of the butterfly also from the south along the Atlantic Coastal Plain.

ACKNOWLEDGMENTS

I wish to thank Harry H. Pavulaan (Virginia State Coordinator for the Southern Lepidopterists' Society; President of The International Lepidoptera Survey) for his insightful comments and additional data regarding occurrences of *N. iole* in the eastern United States.

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Investigation of the Spring Bee Fauna (Hymenoptera: Apoidea) of Seven Woodland Sites in the Coastal Plain of Maryland using Continuously-trapping Arrays of Propylene Glycol Cup Traps

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ABSTRACT: A survey of native and alien bees in seven Coastal Plain woodlands was conducted using a transect of nine colored cups filled with propylene glycol. Cups were placed in stands on the ground and run continuously from the start of bee emergence until after canopy closure when bee activity almost entirely halted nine weeks later. A total of 1439 bees were collected of at least 58 species. Site totals varied from 95 to 320 individuals and were dominated by *Andrena* (particularly *A. erigeniae* Robertson), *Osmia* (particularly *O. taurus* Smith), and *Lasioglossum*. Patterns across sites among genera and species are annotated.

INTRODUCTION

Free flying adult bees (Hymenoptera: Apoidea) are present in closed canopy forests in eastern North America primarily in the spring (Robertson 1928). Within these woodlands, particularly deciduous ones, there is usually a complement of canopy, understory, and shrub blooming woody plants while the forest floor can contain an often dense herbaceous layer of vernal flowers. At times, these resources can be abundant but the composition varies greatly among forest types, ranging from carpets of blooming forbs in the floodplains of large bottomland forests to sparse ericaceous shrub layers in oak-hickory forests. In early successional woodlands, weedy non-native plants at times dominate and spring blooming plants may be absent or in low numbers. Soils with extreme physical or chemical characteristics of deep sand, serpentine, acid, or basic materials also impact the resulting set of blooming plants. All such factors together would, in theory, impact the abundance and composition of bees inhabiting each woodland site.

Bee communities have been studied in a number of forested systems in eastern North America, but always as part of a larger faunal study (Arduser 2011; Hanula and Horn 2011; Shapiro and Droege 2011; Giles and Ascher 2006) or in forest savannah systems (Jean 2010; Bartholomew et al. 2006) or studies of the pollination biology of one to a few flower species (Motten 1986; Motten et al. 1981; Macior 1978; Schemske et al. 1978). Published studies have used malaise traps, netting, trap nests, and bowl traps.

While woodland environments are certainly studied by bee biologists, a general problem in comparing bee studies of any sort is the lack of a comparable protocol and the problem

of how to adjust for when and how often samples were taken. The problem is often one of phenology. You can set your sampling dates any way you like using fixed dates or calculations of degree days or even vegetative presentation, but it is always unclear as to how to correct for major differences in bee phenology changes within and among sites or due to weather problems (see Figure 3). It is better to have a sampling regime that continuously traps bees. Malaise traps do that, but few of us have the budget to afford ($200+ [BioQuip Products 2013]) and replace such traps in numbers sufficient to satisfy the statisticians. However, recent work using continuously-trapping propylene glycol-based colored bowl or cup traps does provide an alternative.

In this study, I demonstrate the use of inexpensive arrays of plastic cups filled with propylene glycol to capture and characterize the bee community of a set of seven woodlands on Maryland's Coastal Plain.

MATERIALS AND METHODS

Seven sites on the Coastal Plain of Maryland were chosen on the properties of the United States Department of Agriculture (USDA) Beltsville Agriculture Research Center (BARC), Beltsville, Maryland and the United States Fish and Wildlife Service (USFWS) Patuxent Research Refuge (PRR), Laurel, Maryland (all sites in Prince George's County) as exemplars of different forest types present in the region (Table 1, Figure 1). Sites were chosen non-randomly for their convenience to roads, to each other, and to the author's office. As such, specimens from traps at all sites could be collected in 1.5 hours if one didn't dawdle.

Table 1. Latitude, longitude, and habitat for each sampling site.

Site	Latitude	Longitude	Habitat
1	39.03207	-76.8686	Stream bottom
2	39.03505	-76.8574	Pine (*Pinus* spp. L.)
3	39.03725	-76.8193	Upland oak-hickory (*Quercus* spp. L./*Carya* spp. Nutt.)
4	39.04410	-76.8157	Upland oak-hickory
5	39.05062	-76.8207	Stream bottom
6	39.05992	-76.8055	Bottomland
7	39.05419	-76.8014	Bottomland

Nine traps were located at each site and were spaced 5 m (16.4 ft) apart. Trap arrays began approximately 15 m (49.2 ft) from the edge of the secondary road and continued to the interior of the woods. Each trap consisted of a short length of plastic electrical conduit with a thin ring of 7.6-cm (3-in) polyvinyl chloride (PVC) drain pipe screwed to the side a short distance from the top (Figure 2). The conduit was pushed or pounded into the ground so that the ring would hold a 355-ml (12-oz) plastic cup upright with the bottom of the cup touching the ground. Each cup had three small weep holes drilled into it just below the lip of the cup to release liquid during heavy rain events. The cups were an opaque white color; one third of them were painted fluorescent blue and one third

Figure 1. Location of the seven sampling sites at the United States Department of Agriculture Beltsville Agriculture Research Center, Beltsville, Maryland and the United States Fish and Wildlife Service Patuxent Research Refuge, Laurel, Maryland. (Map adapted from Google Maps [2012].)

Figure 2. Propylene glycol cup trap.

fluorescent yellow on their interior walls. Fluorescent paints were created using a white latex silicon flat base paint mixed with either yellow or blue fluorescent pigment from Guerra Paint and Pigment. Traps were filled with propylene glycol that had been dyed blue by the plumbing company where it was purchased and had been diluted by approximately half with tap water. A small amount of Ultra Dawn® blue dishwashing liquid was added to the glycol to decrease surface tension and each cup was filled to approximately 7/8^{ths} full. Such traps function in the same way as vane, bowl, and pan traps, passively collecting insects that are attracted to the color of the trap. Traps were initially deployed on 16 March 2011 and were run for 9 weeks ending 19 May 2011 (Table 2).

Table 2. Sampling dates. Week 0 is the date when the arrays were first deployed; the remaining weeks are the dates when samples were collected.

Week	Sampling Date
0	16 MAR 2011
1	23 MAR 2011
2	30 MAR 2011
3	06 APR 2011
4	13 APR 2011
5	19 APR 2011
6	27 APR 2011
7	04 MAY 2011
8	10 MAY 2011
9	19 MAY 2011

Specimens were collected from traps each week. If trap liquids were low, then more was added. There were only two instances in which cups were spilled and contents lost. Trap liquids quickly became discolored and darkened due to detritus from vegetation and specimens and the blue color became unnoticeable. All traps from an individual site were pooled during each sampling period and stored in a freezer until processing (7 sites x 9 weeks = 63 samples). Specimens were washed, dried, pinned, and labeled prior to identification by the author. Trapping was ended when capture rates became very low (fewer than one specimen per array) in May after the canopy had formed and blooming had ceased in the woodland environments. Weather was normal for the season with an exceptionally cool and rainy period occurring during the second trapping week, resulting in few captures (Table 3, Figure 3).

Paleontological Statistical Software Package version 2.14 (Hammer et al. 2001) was used in all analyses.

Following identification and analyses, specimens of uncommon species were dispersed to the United States National Museum of Natural History, Smithsonian Institution; the remainder were destroyed or given away.

Table 3. Captures of all species (except *Andrena erigeniae*) for the seven sites and nine sampling weeks.

	Week									Site
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Site 1	15	1	-	17	12	-	19	2	3	69
Site 2	12	-	53	81	31	9	1	2	-	189
Site 3	1	2	23	54	8	3	1	-	-	92
Site 4	8	1	65	120	42	9	4	-	1	250
Site 5	22	2	24	40	14	6	-	-	-	108
Site 6	40	1	21	24	12	15	6	1	1	121
Site 7	42	-	33	23	11	15	4	2	1	131
Weekly Total	140	7	219	359	130	57	35	7	6	960

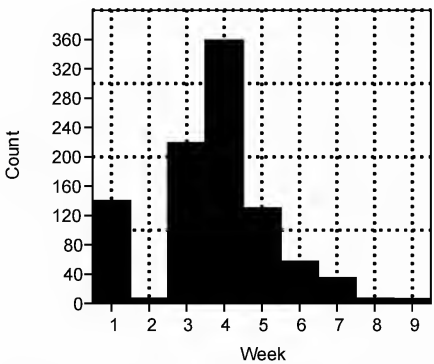

Figure 3. Captures of all bees by sampling week excluding captures of *Andrena erigeniae*. Note that Week 2 was cold and rainy throughout.

RESULTS

A total of 1439 bees were collected representing at least 58 species captured over the nine-week sampling period (Table 4 lists captures of species by sampling site and Table 5 lists captures of species by sampling date).

Bees from the genera *Andrena* Fabricius, *Osmia* Panzer, and *Lasioglossum* Curtis dominated the captures, comprising 91% of all captures from the 16 genera represented (Table 6).

Table 4. Species captures for the seven sampling sites.

Species	Site 1	2	3	4	5	6	7	Total
Family Andrenidae								
Andrena barbara Bouseman & LaBerge	2	-	-	-	-	4	2	8
Andrena bradleyi Viereck	-	-	-	-	-	1	-	1
Andrena carlini Cockerell	2	5	10	26	2	9	6	60
Andrena cressonii Robertson	3	1	-	-	1	-	1	6
Andrena erigeniae Robertson	108	1	3	2	8	168	189	479
Andrena fenningeri Viereck	1	-	-	-	-	-	-	1
Andrena hilaris Smith	1	-	-	-	-	-	-	1
Andrena imitatrix Cresson	-	2	-	-	-	1	1	4
Andrena nasonii Robertson	1	-	-	-	-	-	1	2
Andrena perplexa Smith	8	-	-	-	2	3	1	14
Andrena pruni Robertson	3	2	-	3	-	5	6	19
Andrena rugosa Robertson	-	-	-	-	-	1	2	3
Andrena tridens Robertson	1	-	-	1	-	2	3	7
Andrena vicina Smith	-	-	-	1	1	-	-	2
Andrena violae Robertson	-	1	1	1	1	1	1	6
Andrena (*Trachandrena* Robertson) species	1	1	-	3	-	-	-	5
Family Halictidae								
Agapostemon virescens (Fabricius)	-	1	-	-	-	-	-	1
Augochlora pura (Say)	4	2	-	2	1	-	2	11
Augochlorella aurata (Smith)	-	1	-	-	1	-	-	2
Augochloropsis metallica (Fabricius)	-	-	-	-	-	-	3	3
Halictus ligatus Say or *H. poeyi* Lepeletier	-	-	-	-	-	1	-	1
Halictus rubicundus (Christ)	-	-	1	-	-	-	-	1
Lasioglossum abanci (Crawford)?	-	-	-	-	-	1	1	2
Lasioglossum coeruleum (Robertson)	2	3	1	2	4	3	7	22
Lasioglossum coriaceum (Smith)	-	4	-	-	-	-	-	4
Lasioglossum cressonii (Robertson)	1	15	6	17	4	7	-	50
Lasioglossum ephialtum Gibbs	-	2	-	-	-	-	-	2
Lasioglossum foxii (Robertson)	1	1	-	-	-	1	-	3
Lasioglossum fuscipenne (Smith)	1	1	-	6	-	-	-	8
Lasioglossum gotham Gibbs	1	5	-	-	5	-	5	16
Lasioglossum hitchensi Gibbs	1	-	-	-	-	-	-	1
Lasioglossum imitatum (Smith)	1	-	-	-	-	-	-	1
Lasioglossum macoupinense (Robertson)	-	-	-	-	4	-	-	4
Lasioglossum nigroviride (Graenicher)	-	1	-	-	-	-	-	1
Lasioglossum quebecense (Crawford)	6	-	2	2	35	58	61	164
Lasioglossum subviridatum (Cockerell)	-	36	1	12	2	1	9	61
Lasioglossum taylorae Gibbs?	-	-	-	1	-	-	-	1
Lasioglossum Curtis species A	-	1	-	-	-	-	-	1
Sphecodes Latreille species	-	-	-	-	1	-	-	1
Family Megachilidae								
Osmia atriventris Cresson	-	-	2	2	2	-	-	6
Osmia cornifrons (Radoszkowski)	-	1	3	-	1	1	-	6
Osmia georgica Cresson	1	-	-	-	-	-	-	1
Osmia pumila Cresson	1	3	8	17	8	-	-	37
Osmia taurus Smith	6	79	47	109	26	14	10	291
Osmia virga Sandhouse	-	1	1	6	-	-	-	8
Family Apidae								
Anthophora plumipes (Pallas)	1	1	1	1	-	-	-	4
Apis mellifera Linnaeus	3	-	-	-	-	-	-	3
Bombus bimaculatus Cresson	1	1	2	7	2	-	-	13
Bombus griseocollis (DeGeer)	-	-	-	2	-	-	-	2
Ceratina calcarata Robertson	-	4	-	-	1	-	-	5
Ceratina strenua Smith	-	2	-	-	-	-	-	2
Habropoda laboriosa (Fabricius)	-	-	1	1	-	-	-	2
Nomada armatella Cockerell	-	-	-	1	-	-	-	1
Nomada composita Mitchell	2	-	-	-	-	-	1	3
Nomada denticulata Robertson	-	2	-	2	-	-	-	4
Nomada depressa Cresson	-	1	-	-	-	-	-	1
Nomada illinoensis Robertson or *N. sayi* Robertson	1	1	-	2	-	-	-	4
Nomada lehighensis Cockerell	2	-	-	-	-	1	1	4
Nomada lehighensis Cockerell?	1	-	-	-	-	-	-	1
Nomada luteoloides Robertson	3	1	2	3	3	4	5	21
Nomada pygmaea Cresson	6	6	2	18	-	1	1	34
Nomada Scopoli “bidentate” species	-	1	1	1	1	1	1	6
Xylocopa virginica (Linnaeus)	-	-	-	1	-	-	-	1
Total Number of Bees	177	190	95	252	116	289	320	1439
Number of Species	30	33	19	29	23	23	24	58

Table 5. Species captures for the nine sampling weeks.

Species	Week 1	2	3	4	5	6	7	8	9	Total
Family Andrenidae										
Andrena barbara	-	-	1	4	1	-	2	-	-	8
Andrena bradleyi	-	-	-	-	-	1	-	-	-	1
Andrena carlini	9	-	22	22	4	3	-	-	-	60
Andrena cressonii	2	-	-	-	1	1	2	-	-	6
Andrena erigeniae	63	5	29	36	23	41	242	25	15	479
Andrena fenningeri	-	-	-	-	-	-	1	-	-	1
Andrena hilaris	-	-	-	-	-	-	1	-	-	1
Andrena imitatrix	-	-	1	-	1	1	-	1	-	4
Andrena nasonii	-	-	-	-	1	1	-	-	-	2
Andrena perplexa	-	-	2	-	-	4	8	-	-	14
Andrena pruni	-	-	-	5	8	6	-	-	-	19
Andrena rugosa	-	-	-	3	-	-	-	-	-	3
Andrena tridens	-	1	2	3	1	-	-	-	-	7
Andrena vicina	-	-	-	1	1	-	-	-	-	2
Andrena violae	-	-	2	-	2	1	1	-	-	6
Andrena (*Trachandrena*) species	-	-	-	4	-	1	-	-	-	5
Family Halictidae										
Agapostemon virescens	1	-	-	-	-	-	-	-	-	1
Augochlora pura	-	-	1	1	4	1	1	2	1	11
Augochlorella aurata	-	-	1	1	-	-	-	-	-	2
Augochloropsis metallica	-	-	-	-	2	1	-	-	-	3
Halictus ligatus or *H. poeyi*	-	-	-	-	-	1	-	-	-	1
Halictus rubicundus	-	-	-	-	1	-	-	-	-	1
Lasioglossum abanci?	1	-	1	-	-	-	-	-	-	2
Lasioglossum coeruleum	6	-	-	13	2	1	-	-	-	22
Lasioglossum coriaceum	1	-	-	1	-	1	1	-	-	4
Lasioglossum cressonii	7	-	2	18	14	6	1	1	1	50
Lasioglossum ephialtum	-	-	-	-	-	2	-	-	-	2
Lasioglossum foxii	1	-	-	-	1	-	-	-	1	3
Lasioglossum fuscipenne	-	-	2	5	1	-	-	-	-	8
Lasioglossum gotham	9	1	2	-	3	-	-	1	-	16
Lasioglossum hitchensi	-	-	-	-	-	-	1	-	-	1
Lasioglossum imitatum	-	-	-	-	-	-	1	-	-	1
Lasioglossum macoupinense	-	-	-	2	2	-	-	-	-	4
Lasioglossum nigroviride	-	-	-	1	-	-	-	-	-	1
Lasioglossum quebecense	84	-	27	34	6	6	5	2	-	164
Lasioglossum subviridatum	10	-	13	32	6	-	-	-	-	61
Lasioglossum taylorae?	-	-	-	-	1	-	-	-	-	1
Lasioglossum species A	-	-	-	1	-	-	-	-	-	1
Sphecodes species	-	-	-	1	-	-	-	-	-	1
Family Megachilidae										
Osmia atriventris	-	-	1	-	3	2	-	-	-	6
Osmia cornifrons	-	-	1	2	2	1	-	-	-	6
Osmia georgica	-	-	-	-	-	-	1	-	-	1
Osmia pumila	1	-	7	22	7	-	-	-	-	37
Osmia taurus	1	3	118	140	23	5	1	-	-	291
Osmia virga	1	-	3	4	-	-	-	-	-	8
Family Apidae										
Anthophora plumipes	-	-	1	-	1	-	1	-	1	4
Apis mellifera	1	-	-	-	1	-	-	-	1	3
Bombus bimaculatus	1	1	3	7	1	-	-	-	-	13
Bombus griseocollis	-	-	1	-	-	1	-	-	-	2
Ceratina calcarata	-	-	2	1	-	2	-	-	-	5
Ceratina strenua	-	-	-	1	-	1	-	-	-	2
Habropoda laboriosa	-	-	-	1	1	-	-	-	-	2
Nomada armatella	-	-	-	-	1	-	-	-	-	1
Nomada composita	2	-	-	-	1	-	-	-	-	3
Nomada denticulata	-	-	-	-	3	1	-	-	-	4
Nomada depressa	-	-	-	-	1	-	-	-	-	1
Nomada illinoensis or *N. sayi*	-	-	-	1	3	-	-	-	-	4
Nomada lehighensis	2	-	1	-	-	1	-	-	-	4
Nomada lehighensis?	-	1	-	-	-	-	-	-	-	1
Nomada luteoloides	-	-	1	11	5	2	2	-	-	21
Nomada pygmaea	-	-	1	17	12	2	1	-	1	34
Nomada "bidentate" species	-	-	-	-	2	1	3	-	-	6
Xylocopa virginica	-	-	-	-	-	-	1	-	-	1
Total Number of Bees	203	12	248	395	153	98	277	32	21	1439
Number of Species	19	6	27	29	38	29	20	6	7	58

Table 6. Captures of individuals by genus across the nine sampling weeks.

Family and Genus	Week 1	2	3	4	5	6	7	8	9	Genus Total
Family Andrenidae										
Andrena Fabricius	74	6	59	78	43	60	257	26	15	618
Family Halictidae										
Agapostemon Guérin-Méneville	1	-	-	-	-	-	-	-	-	1
Augochlora Smith	-	-	1	1	4	1	1	2	1	11
Augochlorella Sandhouse	-	-	1	1	-	-	-	-	-	2
Augochloropsis Cockerell	-	-	-	-	2	1	-	-	-	3
Halictus Latreille	-	-	-	-	1	1	-	-	-	2
Lasioglossum Curtis	119	1	47	107	36	16	9	4	2	341
Sphecodes Latreille	-	-	-	1	-	-	-	-	-	1
Family Megachilidae										
Osmia Panzer	3	3	130	168	35	8	2	-	-	349
Family Apidae										
Anthophora Latreille	-	-	1	-	1	-	1	-	1	4
Apis Linnaeus	1	-	-	-	1	-	-	-	1	3
Bombus Latreille	1	1	4	7	1	1	-	-	-	15
Ceratina Latreille	-	-	2	2	-	3	-	-	-	7
Habropoda Smith	-	-	-	1	1	-	-	-	-	2
Nomada Scopoli	4	1	3	29	28	7	6	-	1	79
Xylocopa Latreille	-	-	-	-	-	-	1	-	-	1
Weekly Total	203	12	248	395	153	98	277	32	21	1439

At the species level, *Andrena erigeniae* Robertson (479 captures, 33%) and the recently established non-native *Osmia taurus* Smith (291 captures, 20%) were captured the most frequently. Capture rates for all species combined, other than *A. erigeniae*, were high for the first five weeks and tapered off rapidly during the last four (Figure 3). *Andrena erigeniae* counts remained relatively steady throughout the time period except during Week 7 when 242 were captured, surpassing the next highest capture period during Week 1 (63) by several times (Table 7 and Figure 4).

Table 7. Captures of *Andrena erigeniae* across the seven sampling sites and nine sampling weeks.

	Week									Site
	1	2	3	4	5	6	7	8	9	Total
Site 1	3	1	-	1	2	-	82	5	14	108
Site 2	-	-	-	-	1	-	-	-	-	1
Site 3	-	-	-	2	-	-	1	-	-	3
Site 4	-	-	-	2	-	-	-	-	-	2
Site 5	1	-	6	1	-	-	-	-	-	8
Site 6	25	-	3	19	16	32	68	4	1	168
Site 7	34	4	20	11	4	9	91	16	-	189
Weekly Total	63	5	29	36	23	41	242	25	15	479

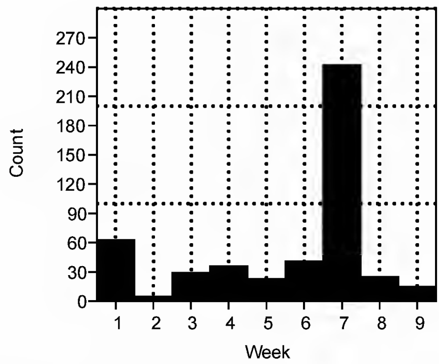

Figure 4. Relationship between week and the number of *Andrena erigeniae* captures.

SUMMARY OF INTERESTING RESULTS FOR SELECT GENERA

Family Andrenidae

Andrena Fabricius: Fifteen species were present. Of those, *A. erigeniae* accounted for 479 of the 618 individuals captured. Unsurprisingly this pollen specialist on Virginia springbeauty, *Claytonia virginica* L. (Portulacaceae) (Davis and LaBerge 1975), was very abundant at the sites with obvious patches of this flower (Sites 1, 6, 7) and only in low numbers elsewhere. *Andrena carlini* Cockerell occurred at all sites but reached its maximum count, 26, at an upland oak-hickory site (Site 4). Nineteen individuals of the relatively uncommon *A. pruni* Robertson were captured with small numbers found at most of the sites. Small numbers of regionally uncommon *Andrena* such as *A. bradleyi* Viereck, *A. hilaris* Smith, *A. rugosa* Robertson, and *A. tridens* Robertson occurred among the plots and may or may not indicate a preference for wooded environments.

Family Halictidae

Agapostemon Guérin-Méneville, *Augochlora* Smith, *Augochlorella* Sandhouse, *Augochloropsis* Cockerell: Only 1 specimen of *Agapostemon*, 2 of *Augochlorella*, and 3 of *Augochloropsis* occurred at three of the sites. This is unsurprising given the author's observation of this group's proclivity for fields. Of the metallic green halictids, 11 individuals were captured of *Augochlora pura* (Say) across most of the sites, mirroring most people's experiences with this species being associated with woodlands and the edges of woodlands (Stockhammer 1966).

Halictus Latreille: Only two captures of *Halictus* species were made, one of *H. ligatus* Say or *H. poeyi* Lepeletier and one of *H. rubicundus* (Christ). Many more would have been expected if these traps were located in fields.

Lasioglossum Curtis: This was perhaps the most interesting group. Normally, I think of *Lasioglossum* as being associated with open field situations and as being pollen and often habitat generalists with the exception of some sand-loving species. However, it seems clear from these data that there is a strong woodland group of *Lasioglossum* species that at least I often overlook. *Lasioglossum coeruleum* (Robertson) occurred across all sites and is known to nest in decaying wood. *Lasioglossum cressonii* (Robertson) is a species that occurs in many habitats, but here occurs in large numbers, particularly in the drier sites. *Lasioglossum gotham* Gibbs is a newly described species (Gibbs 2011) that appears to be associated with woodlands and has been found nesting in upturned tree root masses. *Lasioglossum nigroviride* (Graenicher) is a very uncommon species that occurred in this study only once, but perhaps is to be found more often if woodland situations are more thoroughly checked. *Lasioglossum quebecense* (Crawford) is the most abundant species of *Lasioglossum* captured and clearly avoids the pine and upland oak-hickory sites and favors bottomlands and streamside locations. *Lasioglossum subviridatum* (Cockerell) is a species only uncommonly recorded in the area and is rarely found in fields or open areas, the large numbers documented here indicate that this species may be more common than previously suspected.

Family Megachilidae

Osmia Panzer: A classic spring bee, this group contains a mix of native and introduced species. Unfortunately the non-native *O. taurus* dominate the captures with captures five times those of all the native species of *Osmia* combined. *Osmia lignaria* Say, which is in the same subgenus as *O. taurus* and *O. cornifrons* (another non-native species) is completely absent from this study and perhaps is suffering from competition with this group as it has been captured regularly in these woodlands in the past. *Osmia virga* Sandhouse is an ericaceous specialist and fittingly occurs only in the pine and upland oak-hickory sites with an ericaceous understory.

Family Apidae

Anthophora Latreille: Four specimens of *A. plumipes* (Pallas) occurred across four plots. This species was originally introduced into North America at a site within one kilometer of Site 1 (Batra 1994) and its presence here indicates both its establishment within the region's woodlands and an indication that its numbers may not become overwhelming in native habitats. It is now a regular occurrence throughout the Washington, D.C. area.

Apis Linnaeus: Only 3 Honey Bees, *Apis mellifera* Linnaeus, were captured in this study despite the proximity of many hives associated with the USDA's Bee Research Laboratory, Beltsville, Maryland. All captures occurred at Site 1 which was closest to those hives. *Apis mellifera* tends not to occur regularly in colored bowl-type traps despite being regionally abundant.

Bombus Latreille: Thirteen of the 15 individuals were the early spring *B. bimaculatus* Cresson with the remaining 2 individuals *B. griseocollis* (DeGeer). Although they certainly occur there, there were no *Bombus* captures from the bottomland sites. But similar to *Apis*, they do not often go into bowl traps.

Ceratina Latreille: Of the three very common species present in the region, *C. calcarata* Robertson and *C. strenua* Smith were present, but in small numbers. This follows observations that these species will inhabit spring woodlands while *C. dupla* Say is more associated with dry open sites.

Habropoda Smith: Two specimens of this regionally uncommon blueberry, *Vaccinium* L. spp. (Ericaceae), specialist were captured in the two upland oak-hickory sites which have a strong ericaceous shrub understory.

Nomada Scopoli: As the nest parasites of *Andrena*, and as common as *Andrena* are in this study, it is not surprising to find that there were good numbers of *Nomada* collected. No particular pattern or associations leap out here. While it would be tempting to associate the two most common *Nomada* (*N. pygmaea* Cresson and *N. luteoloides* Robertson) with the two most common *Andrena* (*A. erigeniae* and *A. carlini*), the distribution of their captures seems to bear no relationship.

DISCUSSION

Surveys using propylene glycol cup traps hold promise as inexpensive long-term trapping techniques for native bee species. Such traps appear to diminish the impact of yearly swings in phenological change in bee communities across years and geographical regions, as well as the choice of sampling date within years. They also have the advantage that traps are set only once and servicing these traps can be done on a schedule without regard to weather. Additionally, large numbers of Diptera and other Hymenoptera are captured in these traps and provide potential additional sources of biodiversity and climate change data. These traps are a natural addition to long-term weather stations and monitoring sites in general.

Examples of how to set up a glycol trap array and how to process specimens can be found at the author's internet sites:

Videos: http://www.youtube.com/user/swdroege
Slides: http://www.slideshare.net/sdroege

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A Yearlong Survey of the Bees (Hymenoptera: Apoidea) of a Human-made Habitat Created from Dredged Material: Hart-Miller Island, Chesapeake Bay, Baltimore County, Maryland

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ABSTRACT: In 2009, a “bee bowl” survey was conducted on Hart-Miller Island, which is located off the mouth of Back River in the Northern Chesapeake Bay, Baltimore County, Maryland. Hart-Miller Island is mostly human-made and was created as a site for receiving dredged material from Chesapeake Bay shipping channels and the approach channels to Baltimore Harbor. Five or six 20-bowl transects, each from a different habitat, were run on 18 sampling days from 4 April 2009 through 17 March 2010. A total of 4446 bees were collected, representing 5 families, 27 genera, and at least 86 species.

INTRODUCTION

In 1996, I began conducting faunistic surveys on Hart-Miller Island (HMI) in the northern Chesapeake Bay, Baltimore County Maryland. These began as bird surveys and eventually mammals, reptiles, amphibians, fish, and insects were added. The insect surveys began with butterflies and eventually added dragonflies, damselflies, and other insects (Scarpulla 2008a, 2008b, 2011). In 2008, Samuel W. Droege (United States Geological Survey [USGS], Patuxent Wildlife Research Center [PWRC], Native Bee Inventory and Monitoring Laboratory [BIML], Beltsville, Maryland) proposed that I conduct a survey of the native bees of HMI using the protocols outlined in Droege (2008). To help prepare for the 2009 field season, I attended the “Native Bee Identification, Ecology, Research, and Monitoring” workshop offered at BIML in December 2008.

STUDY SITE

Hart-Miller Island is located in Baltimore County, Maryland, just off the mouth of Back River in the northern Chesapeake Bay (Figure 1). Hart-Miller Island was created from the remnants of Hart Island and Miller Island. The original two islands were gradually eroding away due to storms and wave action. In 1981, the State of Maryland began the creation of HMI from material that was dredged from Baltimore Harbor, its approach channels, and channels in the upper Chesapeake Bay. The newly created island was made up of two sections: Hart-Miller Island State Park (HMI-SP) and the Hart-Miller Island Dredged Material Containment Facility (HMI-DMCF). Six locations on HMI were selected for this survey.

The six survey sites (transects) were selected based on differing habitats (Figure 2 and Table 1). Transect 1 followed the edge of a sandy path leading from the gravel perimeter

Figure 1. Map of Chesapeake Bay showing Hart-Miller Island. (Map adapted from Google Earth 7.0.2.8415. Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Image © 2013 TerraMetrics. [accessed 6 February 2013].)

Figure 2. Transect locations on Hart-Miller Island. (Map adapted from Google Earth 7.0.2.8415. Image © 2013 DigitalGlobe. [accessed 6 February 2013].)

road of HMI-DMCF to the beach area of HMI-SP (Figure 3). Transect 1 was bordered by shrubby vegetation. Transect 2 followed the edge of a trail through the northern deciduous woodland of HMI-SP (Figure 4). Transect 2 was run only in the early spring (six dates) and late fall (two dates) when there was an open canopy. The dominant vegetation was sweetgum, *Liquidambar styraciflua* L. (Hamamelidaceae), and willow oak, *Quercus phellos* L. (Fagaceae). Transect 3 followed the edge of a mowed grassy path into an abundantly flowering meadow in the South Cell of HMI-DMCF (Figure 5). Sweetclover, *Melilotus officinalis* (L.) Lam. (Fabaceae), was abundant. Transect 4 was sited along the edge of the gravel perimeter road of HMI-DMCF where it bordered a tidal marsh (Figure 6). An abundance of eastern baccharis, *Baccharis halimifolia* L. (Asteraceae), was present. Transect 5 bordered the gravel interpretive trail adjacent to the tidally-filled water supply pond for the South Cell of HMI-DMCF (Figure 7). Warm-season grasses and shrubby vegetation on sandy soils were present here. Transect 6 was sited along the grassy edge of the gravel perimeter road of HMI-DMCF where it bordered a grove of loblolly pines, *Pinus taeda* L. (Pinaceae) (Figure 8).

Table 1. Latitude, longitude, and habitat for each transect.

Transect	Latitude	Longitude	Habitat
1	39.2524°	- 76.3722°	sandy path and edge of sandy beach
2	39.2518°	- 76.3741°	deciduous woodland trail
3	39.2501°	- 76.3749°	grassy meadow path
4	39.2492°	- 76.3775°	gravel roadside along tidal marsh
5	39.2468°	- 76.3805°	gravel trailside along pond
6	39.2438°	- 76.3840°	gravel roadside along loblolly pines

MATERIALS AND METHODS

The procedures used in this survey were based on *The Very Handy Manual: How to Catch and Identify Bees and Manage a Collection* (Droege 2008). Surveys were not conducted during inclement or cloudy weather. Each transect was composed of 20 "bee bowls" (i.e., pan traps). Bee bowls are white, 96.1-ml (3.25-oz) "Solo® soufflé portion cups." Seven bowls were painted fluorescent blue and seven were painted fluorescent yellow. The seven blue, seven yellow, and six unpainted white bowls made up the transect. The colors alternated sequentially and were placed approximately 5 m (16.4 ft) apart in a straight or curved transect depending on the geography of the site. Bowls were placed where they would receive maximum sun and were not placed under overhanging vegetation. Each bowl was partially filled with water containing a small amount of Ultra Dawn® blue dishwashing liquid. The detergent lowered the water's surface tension so that any bees landing in the bowl sank below the water's surface. The bowls were deployed for approximately 5 hours per sampling day, which was the maximum available sampling time due to the time constraint of the boat's schedule to and from the island. While the bowls were deployed, I undertook limited opportunistic netting.

Figure 3. Transect 1: Sandy path and sandy beach area. (17 March 2010)

Figure 4. Transect 2: Deciduous woodland trail. (17 March 2010)

Figure 5. Transect 3: Grassy meadow path. (17 March 2010)

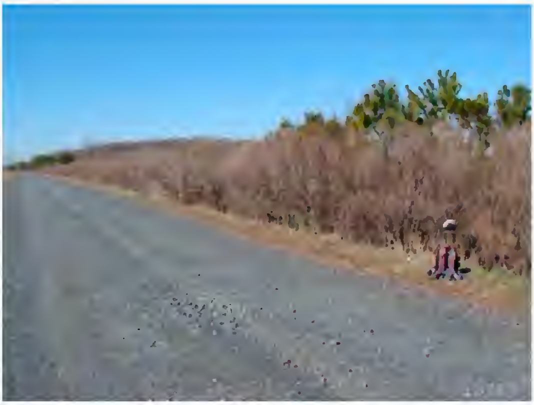

Figure 6. Transect 4: Gravel roadside along tidal marsh. (17 March 2010)

Figure 7. Transect 5: Gravel trailside along pond. (17 March 2010)

Figure 8. Transect 6: Gravel roadside along loblolly pines. (17 March 2010)

At the end of the 5-hour sampling period, the contents of the 20 bowls of an individual transect were combined and stored in 70% ethyl alcohol in 118.2-ml (4-oz) Nasco WHIRL-PAK® bags. To prevent fouling of the bee specimens by lepidopteran wing scales, any butterflies and moths in the bowls were removed prior to combining the contents. All specimens were brought to BIML where they were washed, dried, pinned, labeled (including matrix barcodes), and identified by me and then confirmed by Droege. Identifications were made using Discover Life's bee species guide and world checklist (Ascher and Pickering 2011). The only specimens not identified by me were the female *Lasioglossum* (*Dialictus* Roberson) specimens which were identified by Droege, and the male *Lasioglossum* (*Dialictus*) specimens which were identified by Jason Gibbs (Postdoctoral Associate, Danforth Lab, Cornell University, Ithaca, New York) who recently completed a revision of the metallic *Lasioglossum* (*Dialictus*) of eastern North America (Gibbs 2011). Michael S. Arduser (Natural History Biologist, Missouri Department of Conservation, St. Charles, Missouri) confirmed and identified the *Sphecodes* Latreille specimens. All specimen data were entered into the Discover Life database (http://www.discoverlife.org/20/q?search=Apoidea).

Statistical estimates of true species richness were computed using the software package EstimateS© (Colwell 2009) and SPECRICH (Hines 1996).

RESULTS

A total of 4446 bees were collected, representing 5 of the 6 North American families, 27 genera, and at least 86 species (Table 2). The Apidae had the most genera represented, while the Halictidae exhibited the most species and individuals.

Table 2. Number of taxa caught per family.

Family	Common Name	Genera	Species	Individuals
Colletidae	Plasterer Bees	2	5	31
Andrenidae	Mining Bees	3	13	52
Halictidae	Sweat Bees	7	32	3372
Melittidae	Oil-collecting Bees	0	0	0
Megachilidae	Leafcutter, Mason, Resin Bees	6	18	210
Apidae	Bumble, Carpenter, Digger, Honey Bees	9	18	781
Total		27	86	4446

Table 3 shows the species captured per transect or by netting. Fifty-seven species were captured only in bee bowls. Twenty-four species were captured both in bee bowls and by netting. Five species were captured only by netting (*Colletes nudus* Robertson, *Andrena miserabilis* Cresson, *Sphecodes confertus* Say, *Anthidium oblongatum* [Illiger], and *Coelioxys octodentata* Say). Each of these five "netted only" species was represented by a single specimen.

Table 4 shows the species captured per sampling date with a spring peak on 19 May (n = 867) and a fall peak on 9 November (n = 708).

Table 3. Species captured per transect or by netting. Transect 2 (deciduous woodland) was sampled only before leaf out (six early spring dates) and after leaf fall (two late fall dates). **I** = purposely introduced in North America, **A** = accidentally introduced (or possibly naturally colonized) in North America (Droege 2012).

Species	Transect 1	2	3	4	5	6	By Net	Total
Family Colletidae								
Colletes nudus Robertson	-	-	-	-	-	-	1	1
Hylaeus affinis Smith or *H. modestus* Say	2	-	1	3	2	1	1	10
Hylaeus mesillae (Cockerell)	5	-	2	-	1	-	-	8
Hylaeus nelumbonis (Robertson)	1	-	-	-	-	-	-	1
Hylaeus schwarzii (Cockerell)	6	-	1	1	2	1	-	11
Family Andrenidae								
Andrena atlantica Mitchell	-	-	1	-	-	1	-	2
Andrena barbara Bouseman & LaBerge	-	5	-	-	-	3	6	14
Andrena carlini Cockerell	-	1	-	-	-	-	-	1
Andrena cressonii Robertson	-	-	-	-	-	1	1	2
Andrena erigeniae Robertson	-	3	1	-	-	1	-	5
Andrena imitatrix Cresson	-	1	-	-	-	-	1	2
Andrena miserabilis Cresson	-	-	-	-	-	-	1	1
Andrena nasonii Robertson	1	1	1	-	-	3	2	8
Andrena vicina Smith	1	1	-	-	-	1	1	4
Andrena violae Robertson	-	1	3	1	2	1	-	8
Andrena (*Trachandrena* Robertson) species	-	1	-	-	-	-	2	3
Calliopsis andreniformis Smith	-	-	1	-	-	-	-	1
Perdita octomaculata (Say)	-	-	-	-	1	-	-	1
Family Halictidae								
Agapostemon sericeus (Forster)	-	-	-	-	-	1	-	1
Agapostemon splendens (Lepeletier)	255	2	54	155	69	205	16	756
Agapostemon texanus Cresson	1	-	1	-	-	-	-	2
Agapostemon virescens (Fabricius)	4	-	6	8	11	4	-	33
Augochlora pura (Say)	1	-	-	-	1	-	-	2
Augochlorella aurata (Smith)	33	-	131	194	138	77	1	574
Augochloropsis metallica (Fabricius)	-	-	-	-	-	1	-	1
Halictus confusus Smith	1	-	1	-	-	-	-	2
Halictus ligatus Say or *H. poeyi* Lepeletier	13	-	181	23	145	43	5	410
Halictus tectus Radoszkowski – **A**	2	-	72	1	-	1	-	76
Lasioglossum admirandum (Sandhouse)	-	-	10	24	13	12	2	61
Lasioglossum admirandum (Sandhouse)?	-	-	1	-	1	-	-	2
Lasioglossum bruneri (Crawford)	1	-	8	7	23	20	-	59
Lasioglossum callidum (Sandhouse)	-	-	78	13	95	6	-	192
Lasioglossum coreopsis (Robertson)	-	-	2	-	10	1	-	13
Lasioglossum ephialtum Gibbs	-	-	-	1	2	-	-	3
Lasioglossum ephialtum Gibbs?	-	1	-	-	-	-	-	1
Lasioglossum fuscipenne (Smith)	-	-	-	-	-	2	-	2
Lasioglossum hitchensi Gibbs	18	1	89	74	117	86	1	386
Lasioglossum hitchensi Gibbs or *L.weemsi* (Mitchell)	-	-	6	8	2	15	-	31
Lasioglossum illinoense (Robertson)	1	-	-	-	-	-	-	1
Lasioglossum imitatum (Smith)	-	-	-	-	-	1	-	1
Lasioglossum leucocomum (Lovell)	-	-	1	-	-	-	-	1
Lasioglossum leucocomum (Lovell)?	1	-	-	-	-	1	-	2
Lasioglossum lustrans (Cockerell)	-	-	-	-	-	1	-	1

Species	Transect 1	2	3	4	5	6	By Net	Total
Lasioglossum oblongum (Lovell)	-	-	-	-	2	2	-	4
Lasioglossum pilosum (Smith)	195	5	126	45	101	43	1	516
Lasioglossum platyparium (Robertson)	1	-	9	4	8	10	-	32
Lasioglossum tegulare (Robertson)	10	-	57	4	39	24	-	134
Lasioglossum trigeminum Gibbs	-	-	10	1	7	1	-	19
Lasioglossum versatum (Robertson)	-	-	2	-	-	-	-	2
Lasioglossum weemsi (Mitchell)	-	-	-	1	-	-	-	1
Lasioglossum zephyrum (Smith)	2	2	20	3	3	7	-	37
Lasioglossum Curtis unknown species	2	-	1	2	1	-	-	6
Sphecodes atlantis Mitchell	-	-	4	-	-	1	-	5
Sphecodes confertus Say	-	-	-	-	-	-	1	1
Sphecodes illinoensis (Robertson)	2	-	-	-	-	-	-	2
Family Megachilidae								
Anthidium oblongatum (Illiger) – **A**	-	-	-	-	-	-	1	1
Coelioxys octodentata Say	-	-	-	-	-	-	1	1
Coelioxys sayi Robertson	-	-	1	-	-	1	-	2
Hoplitis pilosifrons (Cresson)	2	-	14	3	32	12	-	63
Hoplitis producta (Cresson)	-	-	-	-	-	1	-	1
Megachile brevis Say	-	-	2	5	4	1	1	13
Megachile concinna Smith – **A**	-	-	1	-	-	-	-	1
Megachile gemula Cresson	-	-	-	-	1	-	-	1
Megachile mendica Cresson	1	-	1	-	1	-	1	4
Megachile montivaga Cresson	-	-	-	1	-	-	-	1
Megachile texana Cresson	-	-	1	1	1	-	-	3
Osmia atriventris Cresson	-	1	1	-	-	-	-	2
Osmia cornifrons (Radoszkowski) – **I**	1	3	2	-	1	-	-	7
Osmia georgica Cresson	-	-	-	-	-	1	-	1
Osmia lignaria Say	-	1	-	-	-	-	-	1
Osmia pumila Cresson	6	30	18	4	5	20	1	84
Osmia taurus Smith – **A**	1	11	1	-	2	-	1	16
Stelis lateralis Cresson	-	-	1	1	5	1	-	8
Family Apidae								
Apis mellifera Linnaeus – **I**	1	-	3	3	2	1	23	33
Bombus fervidus (Fabricius)	-	-	1	1	-	-	-	2
Bombus griseocollis (DeGeer)	-	-	2	-	1	3	12	18
Bombus impatiens Cresson	1	1	8	1	4	4	33	52
Ceratina calcarata Robertson	-	-	1	-	1	-	-	2
Ceratina dupla Say	35	3	95	107	67	9	2	318
Habropoda laboriosa (Fabricius)	1	8	-	3	3	3	5	23
Melissodes comptoides Robertson	-	-	1	-	-	-	-	1
Melitoma taurea (Say)	1	-	-	-	-	-	-	1
Nomada articulata Smith	-	-	-	-	1	12	-	13
Nomada australis Mitchell	-	-	-	1	-	1	-	2
Nomada denticulata Robertson	-	1	-	-	-	-	-	1
Nomada imbricata Smith	-	1	-	-	-	-	-	1
Nomada pygmaea Cresson	-	3	-	-	-	-	-	3
Nomada sayi Robertson	-	1	-	-	-	-	-	1
Nomada Scopoli "bidentate" species	-	1	-	-	1	-	-	2
Ptilothrix bombiformis (Cresson)	24	-	144	34	52	41	7	302
Xylocopa virginica (Linnaeus)	-	-	-	1	-	-	5	6
Total Individuals	633	90	1179	739	980	689	136	4446
Total Species	33	25	48	33	40	46	29	86

Table 4. Species captured per sampling date. *Sampling dates that included Transect 2. **I** = purposely introduced in North America, **A** = accidentally introduced (or possibly naturally colonized) in North America (Droege 2012).

Species	Mar 17*	Apr 04*	Apr 18*	May 06*	May 19*	May 30*	Jun 13	Jul 02	Jul 20	Aug 07	Aug 24	Sep 07	Sep 21	Oct 04	Oct 21	Nov 09	Nov 29*	Dec 15*	Total
Family Colletidae																			
Colletes nudus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Hylaeus affinis or *H. modestus*	-	-	-	-	-	-	-	-	-	-	-	-	4	4	2	-	-	-	10
Hylaeus mesillae	-	-	-	-	1	1	3	-	-	-	-	-	-	-	3	-	-	-	8
Hylaeus nelumbonis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Hylaeus schwarzii	-	-	-	-	1	1	1	-	-	-	1	-	1	6	-	-	-	-	11
Family Andrenidae																			
Andrena atlantica	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Andrena barbara	-	3	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
Andrena carlini	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Andrena cressonii	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Andrena erigeniae	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Andrena imitatrix	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Andrena miserabilis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Andrena nasonii	-	-	3	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	8
Andrena vicina	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Andrena violae	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
Andrena (*Trachandrena*) species	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Calliopsis andreniformis	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Perdita octomaculata	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Family Halictidae																			
Agapostemon sericeus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Agapostemon splendens	3	-	5	61	54	10	33	18	2	39	24	10	3	4	91	376	23	-	756
Agapostemon texanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Agapostemon virescens	-	-	-	1	5	7	8	3	1	1	2	-	-	-	-	5	-	-	33
Augochlora pura	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2
Augochlorella aurata	-	-	10	34	284	14	17	14	16	76	23	-	6	8	31	41	-	-	574
Augochloropsis metallica	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Halictus confusus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	2
Halictus ligatus or *H. poeyi*	-	1	16	8	80	18	9	12	14	82	28	10	19	14	77	21	1	-	410
Halictus tectus – **A**	1	-	1	2	26	1	-	4	1	4	6	2	2	1	8	17	-	-	76
Lasioglossum admirandum	-	-	-	6	31	2	-	-	-	2	1	-	-	1	-	18	-	-	61
Lasioglossum admirandum?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Lasioglossum bruneri	-	-	-	7	13	-	-	1	4	15	5	1	-	-	2	11	-	-	59
Lasioglossum callidum	-	2	27	30	53	6	13	7	6	6	7	7	5	1	8	12	2	-	192
Lasioglossum coreopsis	-	-	1	-	4	1	-	1	2	-	1	-	-	-	3	-	-	-	13
Lasioglossum ephialtum	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3
Lasioglossum ephialtum?	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Lasioglossum fuscipenne	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Lasioglossum hitchensi	4	2	38	131	45	2	18	15	12	8	10	6	1	2	21	69	2	-	386
Lasioglossum hitchensi or *L.weemsi*	-	-	-	-	-	-	-	1	-	-	1	-	-	1	2	25	1	-	31
Lasioglossum illinoense	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Lasioglossum imitatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Lasioglossum leucocomum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Lasioglossum leucocomum?	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2
Lasioglossum lustrans	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Species	Mar 17*	Apr 04*	Apr 18*	May 06*	May 19*	May 30*	Jun 13	Jul 02	Jul 20	Aug 07	Aug 24	Sep 07	Sep 21	Oct 04	Oct 21	Nov 09	Nov 29*	Dec 15*	Total
Lasioglossum oblongum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3	-	-	4
Lasioglossum pilosum	1	2	15	37	57	7	29	84	38	91	69	28	6	-	11	40	1	-	516
Lasioglossum platyparium	1	1	5	2	-	-	-	-	1	-	1	2	-	-	9	10	-	-	32
Lasioglossum tegulare	-	-	1	2	16	3	10	10	5	23	27	8	3	3	5	18	-	-	134
Lasioglossum trigeminum	-	-	-	-	4	-	2	1	2	-	1	-	-	1	3	5	-	-	19
Lasioglossum versatum	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
Lasioglossum weemsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Lasioglossum zephyrum	-	-	-	11	1	-	1	-	2	-	2	-	-	-	1	18	1	-	37
Lasioglossum unknown species	-	-	-	-	-	-	-	2	1	-	-	-	-	-	2	1	-	-	6
Sphecodes atlantis	-	-	1	-	-	-	-	1	-	-	1	-	-	-	1	1	-	-	5
Sphecodes confertus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Sphecodes illinoensis	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	2
Family Megachilidae																			
Anthidium oblongatum **– A**	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Coelioxys octodentata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Coelioxys sayi	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2
Hoplitis pilosifrons	-	-	-	-	48	8	3	3	1	-	-	-	-	-	-	-	-	-	63
Hoplitis producta	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Megachile brevis	-	-	-	-	-	-	-	1	4	5	-	-	1	1	1	-	-	-	13
Megachile concinna **– A**	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Megachile gemula	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Megachile mendica	-	-	-	-	-	-	1	-	-	-	-	1	1	1	-	-	-	-	4
Megachile montivaga	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Megachile texana	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	3
Osmia atriventris	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Osmia cornifrons **– I**	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Osmia georgica	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Osmia lignaria	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Osmia pumila	-	-	64	2	13	3	1	1	-	-	-	-	-	-	-	-	-	-	84
Osmia taurus **– A**	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
Stelis lateralis	-	-	-	-	5	2	1	-	-	-	-	-	-	-	-	-	-	-	8
Family Apidae																			
Apis mellifera **– I**	-	-	-	-	-	2	1	3	5	3	6	3	4	6	-	-	-	-	33
Bombus fervidus	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	2
Bombus griseocollis	-	-	1	1	-	1	3	2	4	6	-	-	-	-	-	-	-	-	18
Bombus impatiens	2	-	3	-	1	-	1	1	5	4	6	5	4	3	5	11	1	-	52
Ceratina calcarata	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Ceratina dupla	-	-	28	3	102	30	43	6	22	7	7	1	35	25	7	2	-	-	318
Habropoda laboriosa	-	-	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
Melissodes comptoides	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Melitoma taurea	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Nomada articulata	-	-	-	-	10	3	-	-	-	-	-	-	-	-	-	-	-	-	13
Nomada australis	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2
Nomada denticulata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Nomada imbricata	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Nomada pygmaea	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Nomada sayi	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-		-	1
Nomada "bidentate" species	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Ptilothrix bombiformis	-	-	-	-	-	-	-	-	229	58	13	1	-	1	-	-	-	-	302
Xylocopa virginica	-	-	1	-	-	1	-	-	1	-	1	-	1	1	-	-	-	-	6
Total Individuals	13	11	317	339	867	127	200	193	381	435	246	87	99	88	303	708	32	0	4446

SELECTED SPECIES COMMENTARY

Family Colletidae

Hylaeus affinis Smith or *H. modestus* Say: These ten specimens are females. Currently, the keys on Discover Life cannot be used to separate females of these species; characters are suggested that can be used to “morpho-sort” specimens, but these may or may not be reliable for distinguishing the species (Ascher and Pickering 2011). Arduser (2009) developed a key to the male and female *Hylaeus* species of Missouri. He stated that while the females of the *H. affinis*/*H. modestus* species complex show some recognizable differences, there are four Missouri species in the complex that cannot be reliably separated. Sheffield et al. (2009) used DNA barcoding to study the bee fauna of Nova Scotia. They found that at least three Nova Scotia species comprise the *H. affinis*/*H. modestus* species complex. Additional investigations of this species complex are being conducted by Droege (pers. comm.).

Hylaeus nelumbonis (Robertson): This species is associated with the edges of wetlands in coastal areas (Droege, in litt.).

Hylaeus schwarzii (Cockerell): This species is associated with the edges of wetlands in coastal areas (Droege, in litt.).

Family Andrenidae

Andrena (*Trachandrena* Roberson) species: Three male specimens in the *Trachandrena* subgenus could not be identified to species. Since none of the identified *Andrena* specimens were in the subgenus *Trachandrena*, these three specimens are counted as (at least) one species in the survey list.

Perdita octomaculata (Say): This species is associated with sandy soils (Droege, in litt.).

Family Halictidae

Agapostemon splendens (Lepeletier): This species is associated with sandy soils (Droege, in litt.).

Halictus ligatus Say or *H. poeyi* Lepeletier: These two cryptic species have no known morphological differences and have only been differentiated by allozyme electrophoresis (Carman and Packer 1996) and by mitochondrial DNA (Danforth et al. 1998). The two species show many similarities in their phenology and social biology (Dunn et al. 1998). Packer (1999) investigated the North American distribution of these two species. He found *H. poeyi* occurring along the Coastal Plain of the southeastern United States, ranging from Texas to Virginia. He found *H. ligatus* north and west of these areas, ranging from California to Ontario, Canada. The species were sympatric on the Piedmont Plateau, ranging from Alabama to North Carolina. Closer to Maryland, he found *H. ligatus* in Martinsburg, West Virginia; Natural Bridge, Fancy Gap, and

Nettleridge, Virginia; and Washington, District of Columbia, and found *H. poeyi* in Richmond, Virginia. Based on Packer's findings (1999), and since Hart-Miller Island is located on the Coastal Plain, one could infer that the HMI specimens are most likely *H. poeyi*. Droege (pers. comm.) has been examining numerous specimens of the two species from around the United States and believes that there may be slight morphological differences that could potentially differentiate the two species. Based on his examination of the HMI specimens, he feels that they most likely are *H. poeyi*. Even though the identification of the HMI specimens (77 male, 333 female) leans toward *H. poeyi*, their true identification cannot be made at this time.

Halictus tectus Radoszkowski: This non-native halictid is an accidental introduction to North America that was first discovered on 24 August 2005 in Philadelphia, Pennsylvania, by Droege (Specimen USGS_DRO039393, Ascher and Pickering 2011). The specimen is deposited at PWRC-BIML. This Eurasian species is native from southern Europe to Mongolia. Besides Philadelphia, it has been found in Washington, DC, and in Baltimore and Beltsville, Maryland (Droege 2012). In North America, the species appears to be associated with highly disturbed urban sites especially with non-native vegetation (Droege 2012).

Lasioglossum admirandum (Sandhouse)?: Due to the condition of these two female specimens, they could not be determined definitely as *L. admirandum* (Sandhouse).

Lasioglossum ephialtum Gibbs?: Due to the condition of the one female specimen, it could not be determined definitely as *L. ephialtum* Gibbs.

Lasioglossum hitchensi Gibbs: *Lasioglossum mitchelli* Gibbs (formerly *L. atlanticum* [Mitchell] and, before that, *Dialictus atlanticus* Mitchell) was recently renamed *L. hitchensi* Gibbs (Gibbs 2012).

Lasioglossum hitchensi Gibbs or *L. weemsi* (Mitchell):– The females of both species have been described and are nearly identical except for the T1 hair fan (Gibbs, in litt. [17 October 2012]). Three female specimens with damaged hair fans could not be determined. The male of *L. hitchensi* [then *L. mitchelli*] has been described (Gibbs 2010). The yet to be described male of *L. weemsi* is virtually identical to *L. hitchensi* and DNA analysis will probably be required to sort them definitively (Gibbs, in litt. [17 October 2012]). Twenty-eight male specimens could not be determined.

Lasioglossum leucocomum (Lovell)?: Due to the condition of these two male specimens, they could not be determined definitely as *L. leucocomum* (Lovell).

Lasioglossum lustrans (Cockerell): This is a southern species. The Hart-Miller Island record is the northernmost record on the East Coast (39.2438° N), but not in North America (Ascher and Pickering 2011).

Lasioglossum Curtis unknown species: These six *Lasioglossum* specimens (3 males, 3 females) were in damaged condition and were not identifiable to species.

Family Megachilidae

Anthidium oblongatum (Illiger): The non-native European Wool Carder Bee is an accidental introduction to North America that was first detected in Harrisburg, Pennsylvania, by Alfred G. Wheeler, Jr. on 17 October 1995 (Hoebeke and Wheeler 1999). The specimen is deposited in the Cornell University Insect Collection, Ithaca, New York. *Anthidium oblongatum* is native to Europe and the Near East. It is currently common in the Northeast and in southern Canada and is immigrating into the central states and provinces (Droege 2012).

Megachile concinna Smith: The non-native Pale Leafcutting Bee was probably introduced from Africa to the West Indies in the early 1800s. It was detected in the United States after World War II (Mitchell 1962). The Western Hemisphere distribution currently includes the southern United States, Mexico, and the West Indies (Droege 2012). In North America, this uncommon introduced species is mostly associated with disturbed urban areas (Droege, in litt.).

Osmia cornifrons (Radoszkowski): The non-native Hornfaced Bee is native to eastern China, Korea, and Japan (Droege 2012). It was intentionally introduced by the United States Department of Agriculture (USDA) to North America in Logan, Utah, in 1965 for the pollination of fruit tree crops (Batra 1979, pers. comm.). The introduction was unsuccessful. Subsequently, the species was successfully introduced by USDA at the Beltsville Agricultural Research Center, Beltsville, Maryland, on 8 April 1977 (Batra 1979). Feral populations exist in the Mid-Atlantic and the Northeast. This species is available commercially (Droege 2012).

Osmia taurus Smith: This non-native megachilid was first detected in North America on 16 April 2002 by Droege at the PWRC in Maryland (Specimen USGS_DRO005420, Ascher and Pickering 2011). The specimen is deposited at PWRC-BIML. *Osmia taurus* is native to eastern China and Japan. It is currently found in the Mid-Atlantic and in the Appalachian Mountains (Droege 2012).

Family Apidae

Apis mellifera Linnaeus: The non-native Honey Bee was first introduced to North America from Europe by at least the 1620s (Council of the Virginia Company 1621). It is uncommonly caught in bee bowls. Twenty-three of the 33 HMI specimens were obtained by netting. On 21 September 2009, the numerous *Baccharis halimifolia* along Transect 4 were covered with thousands of nectaring Honey Bees. There are no known colonies of feral Honey Bees on the island but they could possibly occupy a tree hollow in the remnant woodlands. There are no managed hives on the island.

Bombus Latreille species: Bumble bee species are fairly uncommonly caught in bee bowls. Forty-five of the 72 HMI specimens were obtained by netting.

Ceratina dupla Say: Rehan and Sheffield (2011) delineated a new species, *C. mikmaqi* Rehan and Sheffield, from the *C. dupla* species-group based on morphological and molecular characters. Using the morphological characters from Rehan and Sheffield, all 318 of the HMI specimens were identified as *C. dupla*. The fact that 318 of the 320 *Ceratina* were *C. dupla* (only 2 *C. calcarata* Robertson) is noteworthy since locations elsewhere on the mainland, with an equivalent level of sampling, would be expected to yield greater numbers of *C. calcarata* and at least some *C. strenua* Smith, with the possibility that *C. mikmaqi* might even be found (Droege, pers. comm.). This might be an indication that *C. dupla* is more tolerant of dry open conditions such as are found on HMI (Droege, pers. comm.).

Habropoda laboriosa (Fabricius): The Southeastern Blueberry Bee is associated with blueberries in sandy soils.

Nomada Scopoli "bidentate" species: Species in the "bidentate" group are under revision (Droege, pers. comm.) and Discover Life currently is not providing names or identifications for the several species involved (Ascher and Pickering 2011). Two male specimens were in this group. Since none of the identified *Nomada* specimens were in the "bidentate" group, these two specimens are counted as (at least) one species in the survey list.

Xylocopa virginica (Linnaeus): The Eastern Carpenter Bee is uncommonly caught in bee bowls. Five of the six HMI specimens were obtained by netting.

DISCUSSION

Relative Abundance and Evenness: In most natural situations, a small number of species make up the majority of the individuals and a large number of species are much less common (Colwell 2012). By ranking the 86 species found on Hart-Miller Island in descending order from most numerous to least numerous, a rank-abundance curve can be created (Figure 9). From the curve, one can see that only 9 species have more than 100 individuals (*Agapostemon splendens* [n = 756], *Augochlorella aurata* [Smith] [n = 574], *Lasioglossum pilosum* [Smith] [n = 516], *Halictus ligatus* or *H. poeyi* [n = 410], *Lasioglossum hitchensi* [n = 386], *Ceratina dupla* [n = 318], *Ptilothrix bombiformis* [Cresson] [n = 302], *Lasioglossum callidum* [Sandhouse] [n = 192], and *Lasioglossum tegulare* [Robertson] [n = 134]). As evidenced by the long tail present at the right of the curve, the majority of species are represented by considerably fewer numbers of individuals. In a theoretically even population, each species would contain the same number of individuals (high evenness) (Maurer and McGill 2011). In the real world, this is rarely the case. Based on the wide range of the number of individuals per each species as evidenced by the rank-abundance curve, the Hart-Miller Island population exhibits the typical low evenness.

Species Richness: Approximately 400 species of bees have been documented in Maryland (Droege, in litt., 30 July 2013). Approximately 22% (n = 86) of Maryland's bee species were recorded on Hart-Miller Island during this survey.

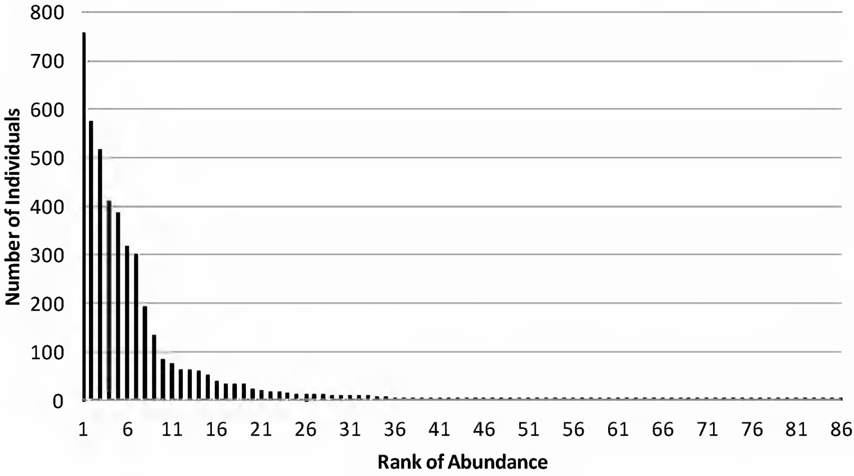

Figure 9. Rank-abundance curve of the number of individuals of each of the 86 species captured on Hart-Miller Island.

Although 86 species were documented in the survey, several statistical estimates of true species richness were computed using the software package EstimateS (Colwell 2009). (Note: The 42 *Lasioglossum* specimens that could not be identified to species [*L. admirandum*?, *L. ephialtum*?, *L. leucocomum*?, *L. hitchensi* or *L. weemsi*, and *L.* unknown species] were not included in this analysis. All five of these *Lasioglossum* species have identified specimens in the survey and the identified specimens are included in the analysis.) The EstimateS data summary and analysis yielded the following results:

Species Observations

- Individuals: 4404 (4446 – 42 = 4404)
- Species Observed: 86
- Sampling Dates: 18
- Singletons (species with only one individual): 27
- Doubletons (species with only two individuals): 15
- Uniques (species that occur on only one sampling date): 41
- Duplicates (species that occur on only two sampling dates): 13

Species Richness Estimators: Abundance-based (i.e., based on the number of individuals of each species in a sample)

- ACE Mean: 123.48
- Chao1 Mean: 107.93 (95% CI: 94.57 – 142.11; SD: 11.14)

Species Richness Estimators: Incidence-based (i.e., based only on the presence of each species in a sample)

- ICE Mean: 157.52
- Chao2 Mean: 141.31 (95% CI: 110.69 – 209.89; SD: 23.75)
- Jack1 Mean (first-order jackknife): 124.72 (SD: 15.95)
- Jack2 Mean (second-order jackknife): 150.29
- Bootstrap Mean: 102.39

Species Richness Estimators: Functional Extrapolation

- MMRuns Mean (Michaelis-Menten richness estimator): 114.55
- MMMeans (1 run) (Michaelis-Menten richness estimator): 100.47

Gotelli and Colwell (2011) state that all species richness estimators should be thought of as computing the minimum boundary of richness. The means of the nine species richness estimators from EstimateS suggest a true species richness for Hart-Miller Island ranging between 100.47 (MMMeans) and 157.52 (ICE Mean) (Figure 10). This implies that with additional sampling, an additional 14 to 72 species could be expected to occur on the island. Since ACE Mean and Chao1 Mean are abundance-based estimators as opposed to the other incidence-based ones, and since abundance values are available for each species, ACE and Chao1 might possibly provide the better estimates. The Chao1 estimate of 107.93 and the ACE of 123.48 imply that an additional 22 to 37 species could be expected to occur on the island.

Estimates of Total Species Richness using SPECRICH

- Another estimate of total species richness was computed from empirical species abundance distribution data using SPECRICH (Hines 1996). The interpolated total species richness was estimated to be 113.00 (SE: 7.35), which falls between the Chao1 and ACE abundance-based estimators (Figure 10).

This implies that an additional 27 species could be expected on the island.

Singletons: Netted versus Bee Bowls: The "netted only" singletons (five species) may be more noteworthy than the "bee bowl" singletons (22 species) since the bee bowl effort was much more systematic and intensive than the netting, suggesting that those species captured only by netting, despite the lower sampling effort, are truly less likely to be sampled by bowl traps than by netting (although for rarely collected species, it could still be by chance that they were captured by a net rather than in a bowl).

Seasonal Bee Abundance: There were three peaks in seasonal bee abundance based on the number of individuals captured on each of the sampling dates (Figure 11). The largest peak (n = 867) occurred in the spring season on 19 May. The most numerous species were *Augochlorella aurata* (n = 284), *Ceratina dupla* (n = 102), and *Halictus ligatus* or *H. poeyi* (n = 80). This was followed by a much smaller summer peak (n = 435) on 7 August. On that date, *Lasioglossum pilosum* (n = 91), *H. ligatus* or *H. poeyi* (n = 82), and *A. aurata* (n = 76) were the most numerous species. (The 20 July "subpeak" [n = 381] approached the peak of 7 August. This "subpeak" was due to an abundance of

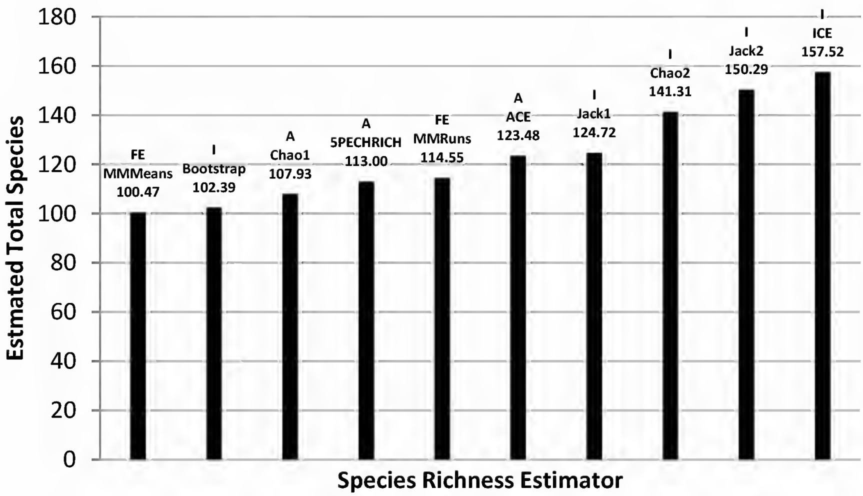

Figure 10: Summary of the estimated total species computed by ten species richness estimators for Hart-Miller Island. A = abundance-based; I = incidence-based; FE = functional extrapolation.

Ptilothrix bombiformis [n = 229]. This occurrence is similar to the one reported by Shapiro and Droege [2011], where, 198 of the 284 individuals captured on 21-22 July 2007 in Calvert County, Maryland, were *P. bombiformis*.) The second highest seasonal peak (n = 708) occurred during the fall season on 9 November. On that date, *Agapostemon splendens* (n = 376) and *Lasioglossum hitchensi* (n = 69) were the most numerous species. This fall peak may have been due to the senescence of most of the flowers near the transects. This dearth of flowering vegetation may have made the bee bowls one of the few choices left for possible visitation by the bees.

Species Seasonality: Table 5 summarizes species occurrences throughout the sampling period. Distinct patterns of species seasonality are apparent. (Note: The 42 *Lasioglossum* specimens that could not be identified to species [*L. admirandum*?, *L. ephialtum*?, *L. leucocomum*?, *L. hitchensi* or *L. weemsi*, and *L.* unknown species] were not included in the following analysis. All five of these *Lasioglossum* species have identified specimens in the survey and the identified specimens are included in the analysis.) Spring produced 59 species, followed by summer, 42, and fall, 41. The higher spring number is primarily due to the presence of the spring-occurring *Andrena*, *Nomada*, and *Osmia* species.

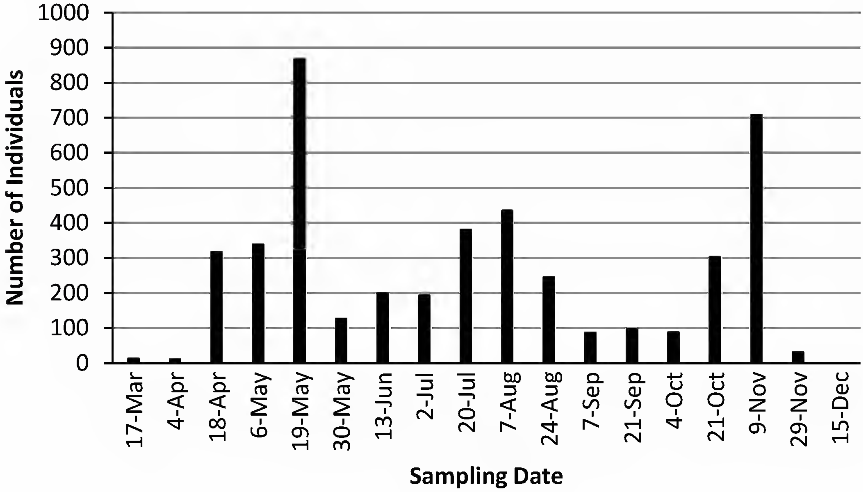

Figure 11. Seasonal bee abundance based on the number of individuals captured per sampling date.

Twenty-nine species occurred only in the spring: *Andrena* (11), *Nomada* (7), *Osmia* (5), *Agapostemon* (1), *Augochloropsis* (1), *Ceratina* (1), *Habropoda* (1), *Lasioglossum* (1), and *Sphecodes* (1). Eleven occurred only in the summer: *Lasioglossum* (2), *Megachile* (2), *Anthidium* (1), *Calliopsis* (1), *Coelioxys* (1), *Colletes* (1), *Hoplitis* (1), *Melissodes* (1), and *Melitoma* (1). Twelve occurred only in the fall: *Lasioglossum* (3), *Hylaeus* (2), *Megachile* (2), *Agapostemon* (1), *Augochlora* (1), *Coelioxys* (1), *Perdita* (1), and *Sphecodes* (1).

Five species occurred only in the spring and summer: *Bombus* (2), *Hoplitis* (1), *Osmia* (1), and *Stelis* (1); three species only in the spring and fall: *Lasioglossum* (2) and *Halictus* (1); and four only in the summer and fall: *Megachile* (2), *Lasioglossum* (1), and *Ptilothrix* (1).

Twenty-two species occurred in all three seasons: *Lasioglossum* (10), *Agapostemon* (2), *Halictus* (2), *Hylaeus* (2), *Apis* (1), *Augochlorella* (1), *Bombus* (1), *Ceratina* (1), *Sphecodes* (1), and *Xylocopa* (1).

Table 5. Species seasonality. The bars represent the presence of an individual species at any time during the season and are not meant to imply that the species was present during the entire season. *Sampling seasons that included Transect 2. **I** = purposely introduced in North America, **A** = accidentally introduced (or possibly naturally colonized) in North America (Droege 2012).

Species	Spring* (Mar, Apr, May)	Summer (Jun, Jul, Aug)	Fall* (Sep, Oct, Nov)
Family Colletidae			
Colletes nudus		———	
Hylaeus affinis or *H. modestus*			———
Hylaeus mesillae	———	———	———
Hylaeus nelumbonis			———
Hylaeus schwarzii	———	———	———
Family Andrenidae			
Andrena atlantica	———		
Andrena barbara	———		
Andrena carlini	———		
Andrena cressonii	———		
Andrena erigeniae	———		
Andrena imitatrix	———		
Andrena miserabilis	———		
Andrena nasonii	———		
Andrena vicina	———		
Andrena violae	———		
Andrena (*Trachandrena*) species	———		
Calliopsis andreniformis		———	
Perdita octomaculata			———
Family Halictidae			
Agapostemon sericeus	———		
Agapostemon splendens	———	———	———
Agapostemon texanus			———
Agapostemon virescens	———	———	———
Augochlora pura			———
Augochlorella aurata	———	———	———
Augochloropsis metallica	———		
Halictus confusus	———		———
Halictus ligatus or *H. poeyi*	———	———	———
Halictus tectus – **A**	———	———	———
Lasioglossum admirandum	———	———	———
Lasioglossum admirandum?			———
Lasioglossum bruneri	———	———	———
Lasioglossum callidum	———	———	———
Lasioglossum coreopsis	———	———	———
Lasioglossum ephialtum	———		———
Lasioglossum ephialtum?	———		
Lasioglossum fuscipenne			———
Lasioglossum hitchensi	———	———	———
Lasioglossum hitchensi or *L. weemsi*		———	———
Lasioglossum illinoense		———	
Lasioglossum imitatum			———
Lasioglossum leucocomum		———	
Lasioglossum leucocomum?			———
Lasioglossum lustrans	———		

Species	Spring* (Mar, Apr, May)	Summer (Jun, Jul, Aug)	Fall* (Sep, Oct, Nov)
Lasioglossum oblongum		—	—
Lasioglossum pilosum	—	—	—
Lasioglossum platyparium	—	—	—
Lasioglossum tegulare	—	—	—
Lasioglossum trigeminum	—	—	—
Lasioglossum versatum	—		—
Lasioglossum weemsi			—
Lasioglossum zephyrum	—	—	—
Lasioglossum unknown species		—	—
Sphecodes atlantis	—	—	—
Sphecodes confertus	—		
Sphecodes illinoensis			—
Family Megachilidae			
Anthidium oblongatum – **A**		—	
Coelioxys octodentata		—	
Coelioxys sayi			—
Hoplitis pilosifrons	—	—	
Hoplitis producta		—	
Megachile brevis		—	—
Megachile concinna – **A**		—	
Megachile gemula			—
Megachile mendica		—	—
Megachile montivaga			—
Megachile texana		—	
Osmia atriventris	—		
Osmia cornifrons – **I**	—		
Osmia georgica	—		
Osmia lignaria	—		
Osmia pumila	—	—	
Osmia taurus – **A**	—		
Stelis lateralis	—	—	
Family Apidae			
Apis mellifera – **I**	—	—	—
Bombus fervidus	—	—	
Bombus griseocollis	—	—	
Bombus impatiens	—	—	—
Ceratina calcarata	—		
Ceratina dupla	—	—	—
Habropoda laboriosa	—		
Melissodes comptoides		—	
Melitoma taurea		—	
Nomada articulata	—		
Nomada australis	—		
Nomada denticulata	—		
Nomada imbricata	—		
Nomada pygmaea	—		
Nomada sayi	—		
Nomada "bidentate" species	—		
Ptilothrix bombiformis		—	—
Xylocopa virginica	—	—	—
Total Species	59	42	41

Species Habitat Association: The following species showed an association with specific habitats (Table 6). Percentages are based on the number of bees of each species caught in a particular transect (n) versus the total number of bees of that species caught in all transects (N). All examples of percentages greater than or equal to 30% and percentages with n values higher that 100 are detailed below. (Note: The 42 *Lasioglossum* specimens that could not be identified to species [*L. admirandum*?, *L. ephialtum*?, *L. leucocomum*?, *L. hitchensi* or *L. weemsi*, and *L.* unknown species] were not included in this analysis. All five of these *Lasioglossum* species have identified specimens in the survey and the identified specimens are included in the analysis.)

Transect 1: This sandy habitat attracted the following species: *Hylaeus mesillae* (Cockerell) (63% [n = 5, N=8]), *H. schwarzii* (55% [n = 6, N = 11]), *Agapostemon splendens* (34% [n = 255, N = 740), and *Lasioglossum pilosum* (38% [n = 195, N = 515]). Three species were found only in this transect: *Hylaeus nelumbonis* (n = 1), *Lasioglossum illinoense* (Robertson) (n = 1), and *Melitoma taurea* (Say) (n = 1).

Transect 2: This small woodland habitat attracted 25 species including: *Andrena barbara* Bouseman & LaBerge (63% [n = 5, N = 8], *Osmia pumila* Cresson (36% [n = 30, N = 83]), *O. taurus* (73% [n =11, N = 15]), and *Habropoda laboriosa* (44% [n = 8, N = 18]). Six species were found only in this transect: *Andrena carlini* Cockerell (n = 1), *Osmia lignaria* Say (n = 1), *Nomada denticulata* Robertson (n = 1), *N. imbricata* Smith (n = 1), *N. pygmaea* Cresson (n = 3), and *N. sayi* Robertson (n = 1).

Transect 3: This meadow attracted the following species: *Augochlorella aurata* (23% [n = 131, N = 573]), *Halictus ligatus* or *H. poeyi* (45% [n = 181, N = 405], *H. tectus* (95% [n = 72, N = 76), *Lasioglossum callidum* (41% [n = 78, N = 192]), *L. pilosum* (24% [n = 126, N = 515]), *L. tegulare* (43% [n = 57, N = 134]), *L. trigeminum* Gibbs (53% [n = 10, N = 19]), *L. zephyrum* (Smith) (54% [n = 20, N = 37]), *Bombus impatiens* Cresson (42% [n = 8, N = 19]), *Ceratina dupla* (30% [n = 95, N = 316]) and *Ptilothrix bombiformis* (49% [n = 144, N = 295]). Five species were found only in this transect: *Calliopsis andreniformis* Smith (n = 1), *Lasioglossum leucocomum* (n = 1), *L. versatum* (Robertson) (n = 2), *Megachile concinna* (n = 1), and *Melissodes comptoides* Robertson (n = 1).

Transect 4: The edge of the gravel road that bordered the tidal marsh attracted the following species: *Agapostemon splendens* (21% [n = 155, N = 740), *Augochlorella aurata* (34% [n = 194, N = 573]), *Lasioglossum admirandum* (41% [n = 24, N = 59]), *Megachile brevis* Say (42% [n = 5, N = 12]), and *Ceratina dupla* (34% [n = 107, N = 316]). Two species were found only in this transect: *Lasioglossum weemsi* (Mitchell) (n = 1) and *Megachile montivaga* Cresson (n = 1).

Transect 5: The warm-season-grassy edge of the gravel trail near the tidal inflow pond attracted the following species: *Agapostemon virescens* (Fabricius) (33% [n = 11, N = 33]), *Augochlorella aurata* (24% [n = 138, N = 573]), *Halictus ligatus* or *H. poeyi* (36% [n = 145, N =405]), *Lasioglossum bruneri* (Crawford) (39% [n = 23, N = 59]), *L. callidum* (49% [n = 95, N = 192]), *L. coreopsis* (Robertson) (77% [n = 10, N = 13]), *L.*

Table 6. Species habitat association. The table only includes bees captured in bee bowls in each transect (no netting). Percentages are based on the number of bees of each species caught in a particular transect (n) versus the total number of bees of that species caught in all transects (N). Percentages are not calculated for transects containing a species with only one (S), only two (D), only three (T), or only four individuals) (Q). A Total Bees number of 0 indicates the species was captured by netting only. Percentages greater than or equal to 30% and percentages with n values higher that 100 are bolded.

Species	Transect 1	2	3	4	5	6	Total Bees (N)
Family Colletidae							
Colletes nudus	-	-	-	-	-	-	0
Hylaeus affinis or *H. modestus*	D	-	S	T	D	S	9
Hylaeus mesillae	**63%**	-	D	-	S	-	8
Hylaeus nelumbonis	S	-	-	-	-	-	1
Hylaeus schwarzii	**55%**	-	S	S	D	S	11
Family Andrenidae							
Andrena atlantica	-	-	S	-	-	S	2
Andrena barbara	-	**63%**	-	-	-	T	8
Andrena carlini	-	S	-	-	-	-	1
Andrena cressonii	-	-	-	-	-	S	1
Andrena erigeniae	-	T	S	-	-	S	5
Andrena imitatrix	-	S	-	-	-	-	1
Andrena miserabilis	-	-	-	-	-	-	0
Andrena nasonii	S	S	S	-	-	T	6
Andrena vicina	S	S	-	-	-	S	3
Andrena violae	-	S	T	S	D	S	8
Andrena (*Trachandrena*) species	-	S	-	-	-	-	1
Calliopsis andreniformis	-	-	S	-	-	-	1
Perdita octomaculata	-	-	-	-	S	-	1
Family Halictidae							
Agapostemon sericeus	-	-	-	-	-	S	1
Agapostemon splendens	**34%**	D	7%	**21%**	9%	**28%**	740
Agapostemon texanus	S	-	S	-	-	-	2
Agapostemon virescens	Q	-	18%	24%	**33%**	Q	33
Augochlora pura	S	-	-	-	S	-	2
Augochlorella aurata	6%	-	**23%**	**34%**	**24%**	13%	573
Augochloropsis metallica	-	-	-	-	-	S	1
Halictus confusus	S	-	S	-	-	-	2
Halictus ligatus or *H. poeyi*	3%	-	**45%**	6%	**36%**	11%	405
Halictus tectus	D	-	**95%**	S	-	S	76
Lasioglossum admirandum	-	-	17%	**41%**	22%	20%	59
Lasioglossum admirandum?	-	-	S	-	S	-	2
Lasioglossum bruneri	S	-	14%	12%	**39%**	**34%**	59
Lasioglossum callidum	-	-	**41%**	7%	**49%**	3%	192
Lasioglossum coreopsis	-	-	D	-	**77%**	S	13
Lasioglossum ephialtum	-	-	-	S	D	-	3
Lasioglossum ephialtum?	-	S	-	-	-	-	1
Lasioglossum fuscipenne	-	-	-	-	-	D	2
Lasioglossum hitchensi	5%	S	23%	19%	**30%**	22%	385
Lasioglossum hitchens or *L. weemsi*	-	-	19%	26%	D	**48%**	31
Lasioglossum illinoense	S	-	-	-	-	-	1
Lasioglossum imitatum	-	-	-	-	-	S	1
Lasioglossum leucocomum	-	-	S	-	-	-	1
Lasioglossum leucocomum?	S	-	-	-	-	S	2
Lasioglossum lustrans	-	-	-	-	-	S	1

Species	Transect 1	2	3	4	5	6	Total Bees (N)
Lasioglossum oblongum	-	-	-	-	D	D	4
Lasioglossum pilosum	**38%**	1%	**24%**	9%	**20%**	8%	515
Lasioglossum platyparium	S	-	28%	Q	25%	**31%**	32
Lasioglossum tegulare	7%	-	**43%**	Q	29%	18%	134
Lasioglossum trigeminum	-	-	**53%**	S	**37%**	S	19
Lasioglossum versatum	-	-	D	-	-	-	2
Lasioglossum weemsi	-	-	-	S	-	-	1
Lasioglossum zephyrum	D	D	**54%**	T	T	19%	37
Lasioglossum unknown species	D	-	S	D	S	-	6
Sphecodes atlantis	-	-	Q	-	-	S	5
Sphecodes confertus	-	-	-	-	-	-	0
Sphecodes illinoensis	D	-	-	-	-	-	2
Family Megachilidae							
Anthidium oblongatum	-	-	-	-	-	-	0
Coelioxys octodentata	-	-	-	-	-	-	0
Coelioxys sayi	-	-	S	-	-	S	2
Hoplitis pilosifrons	D	-	22%	T	**51%**	19%	63
Hoplitis producta	-	-	-	-	-	S	1
Megachile brevis	-	-	D	**42%**	Q	S	12
Megachile concinna	-	-	S	-	-	-	1
Megachile gemula	-	-	-	-	S	-	1
Megachile mendica	S	-	S	-	S	-	3
Megachile montivaga	-	-	-	S	-	-	1
Megachile texana	-	-	S	S	S	-	3
Osmia atriventris	-	S	S	-	-	-	2
Osmia cornifrons	S	T	D	-	S	-	7
Osmia georgica	-	-	-	-	-	S	1
Osmia lignaria	-	S	-	-	-	-	1
Osmia pumila	7%	**36%**	22%	Q	6%	24%	83
Osmia taurus	S	**73%**	S	-	D	-	15
Stelis lateralis	-	-	S	S	**63%**	S	8
Family Apidae							
Apis mellifera	S	-	T	T	D	S	10
Bombus fervidus	-	-	S	S	-	-	2
Bombus griseocollis	-	-	D	-	S	T	6
Bombus impatiens	S	S	**42%**	S	Q	Q	19
Ceratina calcarata	-	-	S	-	S	-	2
Ceratina dupla	11%	T	**30%**	**34%**	21%	3%	316
Habropoda laboriosa	S	**44%**	-	T	T	T	18
Melissodes comptoides	-	-	S	-	-	-	1
Melitoma taurea	S	-	-	-	-	-	1
Nomada articulata	-	-	-	-	S	**92%**	13
Nomada australis	-	-	-	S	-	S	2
Nomada denticulata	-	S	-	-	-	-	1
Nomada imbricata	-	S	-	-	-	-	1
Nomada pygmaea	-	T	-	-	-	-	3
Nomada sayi	-	S	-	-	-	-	1
Nomada "bidentate" species	-	S	-	-	S	-	2
Ptilothrix bombiformis	8%	-	**49%**	12%	18%	14%	295
Xylocopa virginica	-	-	-	S	-	-	1
Total Individuals	633	90	1179	739	980	689	4310
Total Species	33	25	48	33	40	46	81

hitchensi (30% [n = 117, N = 385]), *L. pilosum* (20% [n = 101, N = 515]), *L. trigeminum* (37% [n = 7, N = 19]), *Hoplitis pilosifrons* (Cresson) (51% [n = 32, N = 63]), and *Stelis lateralis* Cresson (63% [n = 5, N = 8]). Two species were found only in this transect: *Perdita octomaculata* (n = 1) and *Megachile gemula* Cresson (n = 1).

Transect 6: The grassy edge of the gravel road that bordered the loblolly pines attracted the following species: *Agapostemon splendens* (28% [n = 205, N = 740), *Lasioglossum bruneri* (34% [n = 20, N = 59]), *L. platyparium* (Robertson) (31% [n = 10, N = 32]), and *Nomada articulata* Smith (92% [n = 12, N = 13]). Six species were found only in this transect: *Agapostemon sericeus* (Forster) (n = 1), *Augochloropsis metallica* (Fabricius) (n = 1), *Lasioglossum imitatum* (Smith) (n = 1), *L. lustrans* (n = 1), *Hoplitis producta* (Cresson) (n = 1), and *Osmia georgica* Cresson (n = 1).

Other Maryland Surveys: There are few published surveys of Maryland's bee fauna and even fewer published surveys from the surrounding states (Droege, pers. comm.). Mitchell (1960, 1962) summarized known state records as of the early 1960s. Unpublished documents from Krombein and Hurd (1971) and Krombein (1985) summarized records from Plummers Island and vicinity, Montgomery County. More recent articles have covered Beltsville Agricultural Research Center (BARC) and Patuxent Research Refuge (PRR), Prince George's County (Droege 2013), the northeastern port areas of Baltimore [city] and Baltimore County (Droege and Shapiro 2011, 2012); the Dominion Cove Point Liquefied Natural Gas (LNG) facility and vicinity, Calvert County (Shapiro and Droege 2011, 2012); Assateague Island National Seashore (NS), Worcester County (Orr 2010); lost micro-deserts of the Patuxent River, Anne Arundel County (Droege et al. 2009); and Plummers Island and vicinity (Anonymous 2008; Norden 2008).

The more recent surveys (2008 – 2013) were searched to see how many of the Hart-Miller Island species were also present at these other locations. Of the 86 Hart-Miller species, 58 were listed for Plummers Island and vicinity (Anonymous 2008), 56 for Plummers Island and vicinity (Norden 2008), 43 for Dominion Cove Point LNG facility and vicinity (Shapiro and Droege 2011, 2012), 33 for the northeastern port areas of Baltimore and Baltimore County (Droege and Shapiro 2011, 2012), 31 for BARC and PRR (Droege 2013), 27 for Assateague Island NS (Orr 2010), and 2 for the lost micro-deserts of the Patuxent River (Droege et al. 2009). These various studies are not directly comparable since different techniques were utilized for most of them. Two were single-season surveys: spring (Droege 2013) and summer (Droege and Shapiro 2011, 2012); one was not a survey per se (Droege et al. 2009); one was a summary list of species without details (Anonymous 2008); and one was a summary of a multi-year study including historical records (Norden 2008). Of the two remaining surveys, one involved one "sample year" (spring-summer-fall) (Shapiro and Droege 2011, 2012); the other involved three years (Orr 2010). Both of these utilized bee bowls and netting, but with different protocols.

Six of my surveyed species have not been reported previously in any of the above literature. These species are *Colletes nudus*, *Andrena atlantica* Mitchell, *Agapostemon*

sericeus, *Lasioglossum leucocomum*, *L. weemsi*, and *Megachile gemula*. I searched the Discover Life and the Droege databases and found previous Maryland records for five of the six species. I did not find any previous records for *C. nudus*. Although one cannot be certain without accessing all of the various museum collections, it appears that my one opportunistically netted *C. nudus* specimen on 2 July 2009 may be the first known record for Maryland.

Hart-Miller Island: Hart-Miller Island is only 1.2 km (~0.75 mi) from the mainland. It is even closer to Pleasure Island (0.8 km [0.5 mi]), which prior to 1951-52 storm erosion, was actually part of the original Hart Island. The original Hart Island was connected to the mainland by a bridge that traversed a narrow channel (0.28 km [0.18 mi]). The fact that Hart-Miller Island is an island does not appear to impede the colonization of the newer portions of the island (HMI State Park and the HMI Dredged Material Containment Facility). A diverse composition of bee species has colonized these newer areas, either from populations present on the original remnants of Hart Island and Miller Island or by immigration from mainland populations, which is clearly the case for recent exotic species such as *Halictus tectus* and *Osmia taurus*).

SUMMARY

During this survey, a total of 4446 bees were collected, representing 5 families, 27 genera, and at least 86 species. The Hart-Miller Island survey adds new distributional records for Maryland, and in particular, the northern Chesapeake Bay region. The data provided by this survey will provide a baseline for future surveys of the island. As the succession of vegetation proceeds on the island and as climatic conditions change (i.e., global warming), habitats will change which could, in turn, change the composition of the bee fauna.

All specimens are currently in the author's personal collection.

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I thank the management and staff of the Hart-Miller Island Dredged Material Containment Facility and Hart-Miller Island State Park for providing logistical support during the field portion of this project. Without their willingness to provide boat access to-and-from the island, the fieldwork could not have been possible. All of the employees took an interest in the survey and were willing to adjust their activities in the transect areas so as to not impact the study sites.

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COVER PHOTOGRAPH

Common Eastern Bumble Bee, *Bombus impatiens* Cresson (Hymenoptera: Apidae) on hedge false bindweed, *Calystegia sepium* (L.) R. Br. (Convolvulaceae). Hart-Miller Island, Chesapeake Bay, Baltimore County, Maryland. 27 June 2013.

Photographed by James F. Cooper, Maryland Environmental Service